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Aeronautical Engineering REVIEW

June, 1956

TWO HEADS ARE BETTER THAN ONE

It takes *two* experienced fliers—the pilot and the landing signal officer—to make a carrier landing. In the same way, *two* great sources of experience work together at American Bosch Arma Corporation. The recent merger joins American Bosch's cost-saving mass production techniques with Arma's expert technological skill. Result: American Bosch Arma Corporation can now provide Engineering and Manufacturing facilities capable of producing the most accurate and reliable electrical and electronic equipments yet produced —equipments the Armed Forces *must* have for the defense of our nation.

AMERICAN BOSCH ARMA CORPORATION

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Aeronautical Engineering Review

Vol. 15—No. 6 June, 1956

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Cover—Grumman's new transonic fighter-trainer, the F9F-8T, has tandem seats and is 23 in. longer than the basic F9F-8 Cougar jet fighter. It has the same engine, a Pratt & Whitney J48, and the same performance and flying qualities. The F9F-8T is armed with two 20-mm. cannons and can carry several types of rockets or bombs. Grumman Aircraft Engineering Corporation plans to begin delivery of the carrier-based trainers to the Navy this summer.

Published Monthly by the

Institute of the Aeronautical Sciences, Inc.

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To fly close support for Marine riflemen

A masterpiece of combat teamwork is the co-ordination between Marine planes and ground forces. With a Marine pilot on the firing line directing the aircraft above, strikes can be pinpointed where they're needed.

Scheduled to fly with the Marines on such missions is the Douglas A4D Skyhawk. Designed as an attack bomber, this smallest of all carrier-based aircraft is also well adapted for the lightning in-out tactics of close support. Its payload—including nuclear weapons—carries a crippling punch.

Douglas A4D Skyhawk

The agile Skyhawk is only as effective as the pilots who fly it. Now, for the first time, college seniors or recent graduates may apply directly for Pilot Training through a new program known as Marine Aviation Officer Candidate Course. For information, write: Commandant of the U. S. Marine Corps., Code (DI), Washington 25, D. C.

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I.A.S. News Notes

June 1956

CHANUTE AWARD. Alvin Melvin "Tex" Johnston, Chief of Flight Test, Boeing Airplane Company, will be honored by the Institute this year for "a notable contribution made by a pilot to the aeronautical sciences". On June 20, he will be presented the Octave Chanute Award at the annual banquet connected with the IAS National Summer Meeting in Los Angeles. Mr. Johnston, who is 41 years old, was a pilot in a flying circus, a pilot and flight instructor in the Air Force, and a test pilot for Bell Aircraft Corporation before he joined Boeing in 1949 as a test pilot on the B-47 program. During the past 20 years he has flown more than 60 types of airplanes. In 1946, he won the Thompson Trophy Race with a modified P-39. The Thurman H. Bane Award, established 13 years ago by Reuben H. Fleet, Past-President of the Institute, will not be given this year.

A NEW BOOKLET for high school students will be published shortly by the Institute. Entitled "Your Career as an Engineer in Aviation", the illustrated brochure describes plainly what an engineer does in the aviation industry; what interests and abilities he should possess; and what subjects he must study in high school and college. It contains a list of engineering colleges in the United States. Various engineering jobs are defined and described. The booklet is designed primarily to tell the student what to expect in an engineering career in aviation and how to prepare for it.

STANFORD UNIVERSITY'S annual Heat Transfer and Fluid Mechanics Institute, cosponsored by the IAS, will be held in Stanford, Calif., June 21-23. Seventeen papers and a panel discussion will be presented. This year, in addition to the usual papers covering advances in the specific fields of heat transfer and fluid mechanics, two sessions on irreversible thermodynamics have been scheduled for the final day. Three papers will be delivered in the morning, followed by a 2-hour discussion period in the afternoon. Professor S. J. Kline, MIAS, of Stanford, is General Chairman.

THEODORE VON KARMAN, an Honorary Fellow of the Institute, has been honored by the Dutch Government with the decoration of Grand Officer of the Order of Orange-Nassau. He is Chairman of NATO's Advisory Group for Aeronautical Research and Development.

NATIONAL MEETINGS CALENDAR

June 18-21	Summer Meeting, IAS Building, Los Angeles, California.
June 20	Annual Summer Banquet, Biltmore Hotel, Los Angeles, Calif.
Aug. 15-17	Turbine-Powered Air Transportation Meeting, U. S. Grant Hotel, San Diego, California. Exhibits at IAS Building.
Aug. 16	IAS Dinner, U. S. Grant Hotel, San Diego, California.

JOINT MEETINGS CALENDAR

Aug. 20-21	National Telemetering Conference, Biltmore Hotel, Los Angeles. Cosponsored with AIEE, IRE, and ISA.

I.A.S. News Notes (con't.)

SECTION MEETING CALENDAR

June 5 Dayton Section: Levitt's Manor. Reception 6:30 p.m., Dinner 7 p.m., Technical Discussion 8 p.m. "Analog Computers as an Engineering Tool" by Jack A. Rudolph of Goodyear Aircraft Corporation.

June 5-6 Boston Section: Joint Meeting with the Assembly of the Radio Technical Commission for Aeronautics and Boston Section of IRE, Hotel Statler. Theme: "Future Use of the Air Space". June 5: Reception 6 p.m., Dinner 7 p.m. "A Look Ahead at Air Transportation" by T. P. Wright, Vice-President for Research, Cornell University.

June 6 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "A Critique of Non-Linear Supersonic Flow Theory Based on the Slender Elliptical Cone" by Milton Van Dyke.

June 7 Atlanta Section: Officers Club, NAS, Chamblee, Ga. Dinner 6:30 p.m. "Air Transportation" by Colonel William B. Bunker, USA, Commandant, Army Transportation Corps, Material and Supply Command, St. Louis.

June 7 Baltimore Section: Levering Hall, The Johns Hopkins University. Reception 6 p.m., Dinner 7 p.m., Meeting 8:30 p.m. "Engineering Education - 1956 Style" by Leon Z. Seltzer, Head, Aeronautical Engineering Department, West Virginia University.

June 12 Washington Section: Occidental Restaurant. Reception 6 p.m., Dinner 6:45 p.m., Meeting 8 p.m. "Implications of the SAGE System" by Albert G. Hill, Director of Research, Weapons Systems Evaluation Group, Department of Defense.

June 13 Niagara Frontier Section: Cornell Aeronautical Laboratory, 8 p.m. "Some Applications of the Theory of Viscoelasticity to High-Speed Aircraft" by Maurice A. Brull, Head, Analytical Structures Section, Bell Aircraft Corporation.

June 19 Hagerstown Section: Franklin Court Auditorium, 7:30 p.m. A discussion of current and future planned programs of each division of Fairchild Engine and Airplane Corporation. Speakers will be Paul Frizzell, Vice-President; Louis Fahnestock, Director of Projects Administration, Fairchild Aircraft Division; E.C. Leeson, Director of Customer Relations, Engine Division; A. W. Doherty, Contracts and Service Manager, Guided Missiles Division; and Charles W. Paas, Jr., Customer Relations Manager, Stratos Division.

July 10 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Fuel System Icing" by E. R. Schuberth.

July 18 Texas Section: Engineering Auditorium, Arlington State College, 8 p.m. "Atomic-Powered-Aircraft Problems" by Lee Secrest.

July 24 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Some Structural Methods and Materials for High-Temperature Applications" by Robert R. Johnson.

Aug. 14 Los Angeles Section: Confidential Specialist Meeting, IAS Building, 8 p.m. "The Effect of Fuselage Flexibility on the Longitudinal Stability of a Guided Missile" by Norman J. Ryker, Jr.

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IAS News

A Record of People and Events of Interest to Institute Members

Eleventh Flight Propulsion Meeting

C. C. Furnas, R&D Chief, Addresses Dinner Audience in Cleveland on "Power-Plant Trends"

SPEAKING AT A DINNER closing the Institute's Eleventh Annual Flight Propulsion Meeting, Clifford C. Furnas, FIAS, Assistant Secretary of Defense (Research and Development), called for a re-examination of the compromises that have been made in developing jet engines to their present state. The title of his address was "Power-Plant Trends as Seen by a Neophyte."

About 500 IAS members and guests attended the dinner, which followed a day of confidential sessions at the Hotel Carter, Cleveland, on March 9. Registration at the conference was 671.

"Among many factors behind these compromises," said Dr. Furnas, "is the urge, born of military necessity, to fly higher, faster, and farther—often all at the same time, with the same aircraft and the same engine types. Using the same engine type for both bomber and fighter aircraft is an example.

"There are sound and valid reasons for these compromises, but we must not lose perspective. I believe that some of our compromises have not been the best possible ones. As a result, we have worked ourselves into some fantastic situations."

Military aviation's uncompromising demand for speed has spoiled some of our objectivity of design, he suggested.

"In order to go fast," continued Dr. Furnas, "the military jet plane tends to become a tank car with a saddle on it. It's very heavy, but it can't have large wings because of drag. It requires extremely long runways.

"In military aircraft, we might build the desired high performance into missiles, which are rapidly becoming the standard armament. But in transport, either military or civilian, do we really need or want to travel as fast as we are now planning?

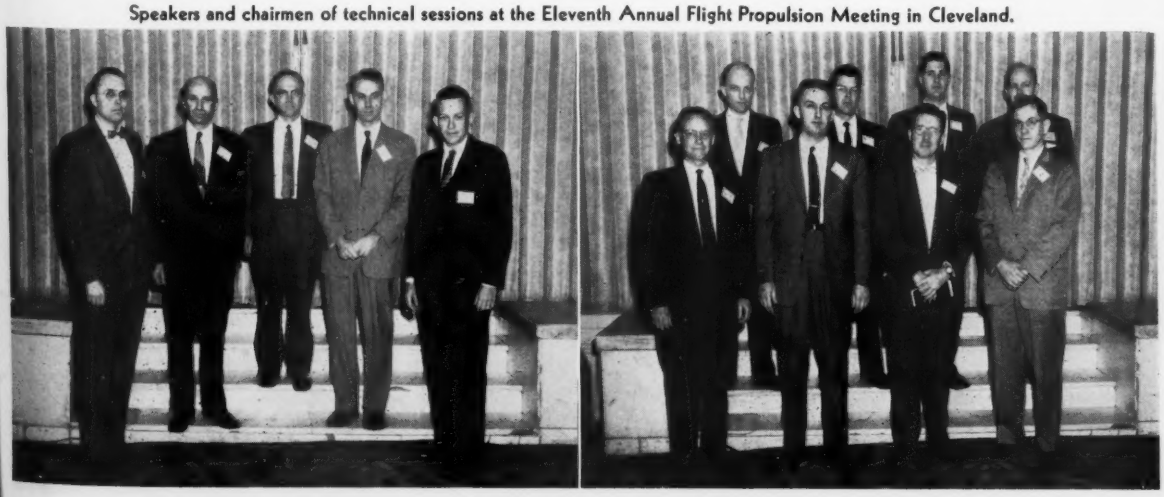
"I doubt if enough engineers have taken a sharp look at the question: Can we not swap some altitude for some concrete? What would an airplane look like if it were designed to have a normal cruise speed of Mach 0.2 at sea level but of Mach 2.0 at 80,000 ft.?

Clifford C. Furnas

Our thinking on the power-plant-airplane combination has been a bit too earth-bound. Let's take a new look at the problems and possibilities of flying at high speed at truly high altitudes and release a segment of the fantastic ingenuity of American engineers to explore this area."

Touching on VTOL fixed-wing aircraft, Dr. Furnas said progress will be delayed because no power plant has been designed to optimize the variables involved in the VTOL problem.

Speakers and chairmen of technical sessions at the Eleventh Annual Flight Propulsion Meeting in Cleveland.



THE GENERAL TIRE
ROCKET POWER

AMERICAN STEEL & WIRE
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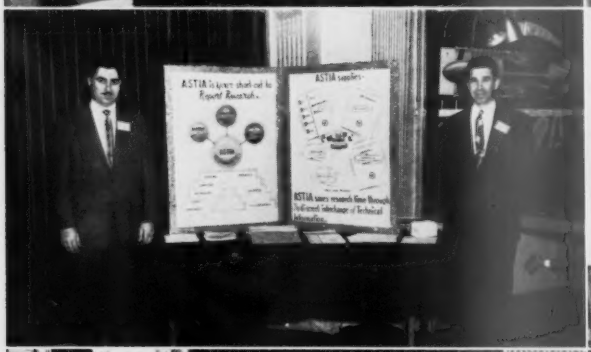
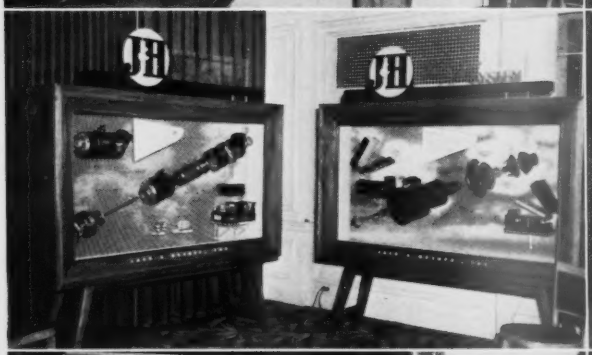


Cleveland Pneumatic

B.F.Goodrich
RUBBER PRODUCTS
FOR THE JET AGE



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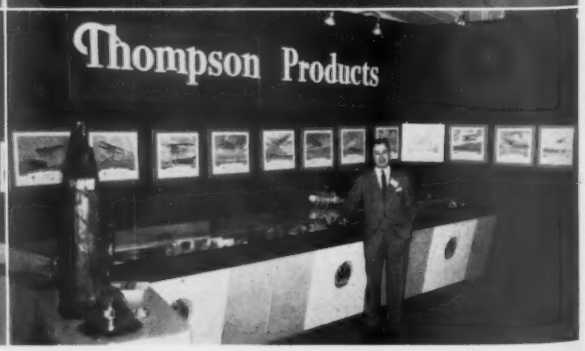

Thompson Products

Arrangements for the Flight Propulsion Meeting were handled by the Cleveland-Akron Section of the Institute, with active support from local industrial firms and officials of Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics. The Program Chairman was John C. Evvard, Chief of the Supersonic Propulsion Division of Lewis Laboratory. Edward R. Sharp, IAS President and Director of Lewis Laboratory, was Toastmaster at the dinner.

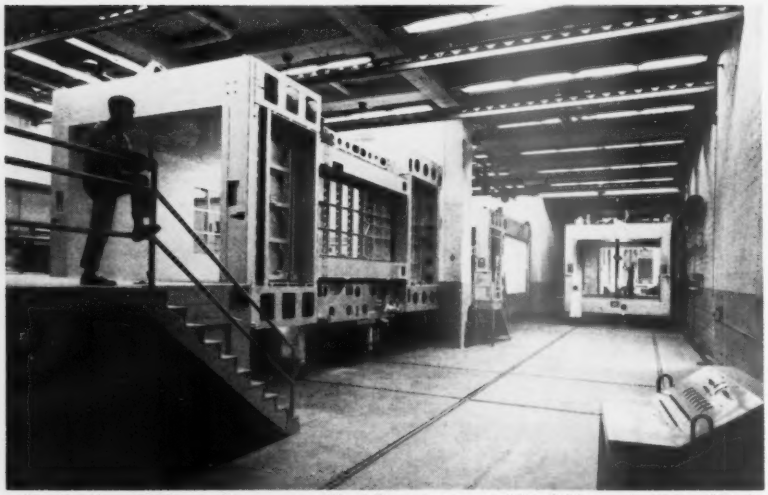
Chairmen of the technical sessions were Addison M. Rothrock, FIAS, Assistant Director for Research (Propulsion), National Advisory Committee for Aeronautics, and Charles Tilgner, Jr., AFIAS, Chief Aeronautical Engineer, Grumman Aircraft Engineering Corp.

For security reasons, the subjects discussed were not disclosed. Eight papers on advanced developments and problems in the flight propulsion field were presented by the following speakers and coauthors: Gerhard Neumann, General Manager of the Jet Engine Department of General Electric Company; Harvey W. Welsh and Russell S. Hall, of the Preliminary Design Section, Allison Division, General Motors Corporation; Edmund B. Maske, Chief of Aerodynamics, Fort Worth Division of Convair, A Division of General Dynamics Corporation; John P. Longwell, of Esso Research and Engineering Company; John S. Winter, Chief Engineer for Power Plants, Marquardt Aircraft Company; R. E. Roy and R. P. Carmichael, of the Power Plant Laboratory, Wright Air Development Center, USAF; R. B. Foster and Howard Jansen, of Bell Aircraft Corporation; and Donald R. Bellman and Kenneth S. Kleinknecht, of NACA's High-Speed Flight Station at Edwards AFB, Calif.

Among members of the Cleveland-Akron Section who took an active part in arranging the meeting were Chairman Karl Arnstein, Secretary William A. Fleming, Willson H. Hunter, Lewis A. Rodert, Irving A. Johnsen, Roger F. Weining, Leonard Goldman, and Capt. Frank J. Rostkowski, USAF.

A reception and technical exhibit, sponsored by manufacturers of the Cleveland-Akron area, preceded the dinner. Hosts for the social hour were the American Steel & Wire Division of United States Steel Corporation, The Cleveland Pneumatic Tool Company, Ferrotherm Company (Aircraft Components Division), General Electric Company, General Tire and Rubber Company (Aerojet-General Corporation), The B. F. Goodrich Company, Goodyear Aircraft Corporation, Jack & Heintz, Inc., Lear, Incorporated (Lear-Romec Division), Pesco Products Division of Borg-Warner Corporation, and Thompson Products, Inc. The exhibits are shown on the opposite page.

(Top) **President Edward R. Sharp *(left)* and John C. Evvard, Program Chairman.**
(Center) **IAS dinner audience hears address by the Hon. C. C. Furnas.**
(Bottom) **One of the technical sessions held in the Hotel Carter, Cleveland.**



The Southern California Cooperative Wind Tunnel, operated by California Institute of Technology, has been modernized at a cost of $8,000,000 and now has supersonic capabilities of Mach 1.8. Two new 20,000-hp. electric motors have boosted the air velocity to 1,400 m.p.h. This photo shows three interchangeable test sections—supersonic, transonic, and subsonic—which can be wheeled into position on tracks. The wind tunnel, which is owned by five aircraft companies, was reopened with a dedication ceremony April 25.

Collected Works of von Kármán to Be Published

Theodore von Kármán, Professor Emeritus of California Institute of Technology and an Honorary Fellow of the IAS, will receive another honor shortly with the publication of four volumes of his technical papers. The noted scientist's 75th birthday was marked by a special issue of the JOURNAL OF THE AERONAUTICAL SCIENCES in May and will be the subject of additional tributes at the IAS banquet in Los Angeles on June 20.

A committee of his friends has announced that the *Collected Works of Theodore von Kármán* will be published next September in four volumes of about 500 pages each. The set will include all his publications up to the present time except those already published in book form. The papers will appear in the original language with the exception of the Hungarian papers, which will be translated into English. About two thirds of the papers are in English, with the remainder in German and French.

Many of the papers to be published are now out of print, according to Prof. W. R. Sears of Cornell University, and many are as important today as when they first appeared.

"The *Collected Works* will be invaluable as a reference book for scientists and engineers," said Dr. Sears. "Even greater benefits will be derived from Dr. von Kármán's unique approach to difficult problems. The precision and clarity with which he brings out the essential elements are complemented by the simplicity and conciseness of his solutions."

The set of four volumes will be printed in England by Butterworths Publications Ltd. of London and will sell for $40. A special limited edition will be sold at $30 per set if ordered in advance of publication. Not available to libraries at this price, the special edition is intended primarily for friends and admirers of Dr. von Kármán. Advance orders should be addressed to the Publication Committee, Collected Works of Theodore von Kármán, California Institute of Technology, Pasadena, Calif. Payment should not be included with the order; subscribers will be billed by the publisher at the time of publication.

Anniversary Volume Honors Sir Geoffrey Taylor

Surveys in Mechanics has been published in England by the Cambridge University Press as an anniversary volume commemorating the 70th birthday of Sir Geoffrey Ingram Taylor, an Honorary Fellow of the IAS and of the Royal Aeronautical Society.

It is a tribute to his scientific achievements in the form of a biographical note and ten contributions by different authors. Each article is a survey of the present position in some field of mechanics in which Sir Geoffrey has been active at some time during the past 50 years and is meant to be an authoritative account suitable for nonspecialist readers.

To aid his experimental work at the Royal Aircraft Factory in Farnborough, Sir Geoffrey learned to fly in 1915. Soon after, he was commissioned as a meteorologist in the Royal Flying Corps with the rank of major. Returning after the war to Trinity College, Cambridge, he taught mathematics and physics there for 32 years, retiring from the faculty in 1951. He has served several terms on the British Aeronautical Research Committee. His many honors for scientific achievement include nine honorary degrees and numerous medals.

Sir Geoffrey celebrated his 70th birthday March 7. During a busy career of teaching, research, and writing, he has found time to enjoy his favorite hobbies, sailing and traveling, with his wife, Stephanie.

The book was edited by G. K. Batchelor, of Trinity College, Cambridge, and R. M. Davies, of University College of Wales, Aberystwyth. (See Book Reviews, page 172.)

Mid-Continent Manufacturing Joins the Institute

Mid-Continent Manufacturing, Inc., with plants in Tulsa, Okla., and Manhattan Beach, Calif., is a new Corporate Member of the Institute. The company's work in the aeronautical field consists of (1) aircraft parts production under subcontracts with the major airframe companies and (2) the development and production of electromechanical equipment and electronic subsystems for aircraft and missile concerns. The latter work is performed by a subsidiary, Datran Engineering Corporation. About 35,000 sq.ft. and 100 employees are devoted to aeronautical activities.

The company's subcontract production work is made up primarily of spar and profile milling of wing and empennage spar caps, stringers, and complex fittings. These parts are currently being produced for the B-52, B-58, B-66, T-33, T2V-1, FJ-4, and P6M aircraft.

Mid-Continent operates six spar mills ranging in length from 30 to 60 ft. and three automatic hydraulic trace profile machines ranging in width from 3 to 5 ft. This equipment, combined with other smaller specialized profiling machinery and a complement of conventional supporting equipment, is believed to make the company one of the largest independent organizations of its type.

Mid-Continent's electromechanical and electronic work consists primarily of the development, production, and marketing of proprietary items, including a complete line of variable-inductance pressure transducers and a line of servo subsystems called "servo-converters." In addition, custom-designed

electronic components and subsystems are produced under contracts with the aircraft industry.

For the past 6 years the company has specialized in the spar and profile milling field. It entered the electronics field 2 years ago.

Corwin D. Denney, MIAS, is President of the firm.

Norden-Ketay Corporation A New Member of IAS

The Norden-Ketay Corporation has joined the Institute as a Corporate Member. This company is engaged in the development and manufacture of aviation ordnance fire-control equipment, navigational systems, air data computers, precision servomotors and synchros, precision aircraft gears, analog digital converters, and other aircraft accessories.

Norden-Ketay Corporation was formed by the merger of The Norden Laboratories Corporation and the Ketay Instrument Corporation in February, 1955.

The corporation now consists of The Norden Laboratories Division, engaged primarily in research and development; the Instruments and Systems Division, which puts primary emphasis on the manufacture of complex analog computers and commercial pressure gages; the Frohman Gear Division, which makes aircraft gears ranging in size from instrument gearing to engine planetary gear reduction assemblies; the Precision Components Division, which produces servomotors, synchros, resolvers, repeaters, etc.; the Boston Electronics Division, specializing in electronic countermeasure work; the Western Division specializing in the manufacture of precision components and in the development of digital computers; and the Gyromechanisms Division, which manufactures compensated reference gyros, rate gyros, oil-floated integrating gyros, and special potentiometers.

The Norden Laboratories Division of the Corporation has a long history stemming from the World War II Norden bombsight. Since that time, this division has developed the Navy Bomb Director Set AN/ASB-1, and it is presently engaged in the development of improved fire-control equipment for Air Force tactical bombers and Navy carrier-based bombers and in the development of infrared seekers, television view-finders, air data computers, jet-engine thrust meters, and other aircraft instrumentation. The Precision Components Division, the company claims, manufactured 80 per cent of the precision aircraft synchros and resolvers used during the Korean conflict.

Norden-Ketay Corporation's executive offices are at 99 Park Avenue, N.Y.

Necrology

Harry T. Brackett

Harry T. Brackett

Harry Thomas Brackett, MIAS, an Experimental Test Pilot with Chance Vought Aircraft, Inc., was killed February 1 while flying an F8U-1 Crusader near Mojave, Calif. The accident occurred during a routine test flight from the Marine Corps Auxiliary Air Station there.

The 30-year-old flier graduated from the University of Maryland as an Aeronautical Engineer in 1950 and obtained his Master's degree in Aeronautical Engineering at California Institute of Technology. He was a Navy fighter pilot before joining Chance Vought 5 years ago.

A native of Sapulpa, Okla., Mr. Brackett joined the Navy in 1944 as an Aviation Cadet and received his wings in December, 1945. He also attended the Navy's school for test pilots at Patuxent River, Md.

Mr. Brackett lived in Palmdale, Calif. He had been transferred there a year ago from Chance Vought's Dallas plant to take part in the F8U-1 flight-test program. He was a member of the Texas Section of IAS and a member of Tau Beta Pi, Phi Kappa Phi, and the Odd Fellows.

He is survived by his wife, Lois.

Zulime W. Diehl

Miss Zulime Whitney Diehl, MIAS, of Washington, D.C., died of cancer on March 27 in a Washington hospital. She was 30 years old.

The daughter of Capt. Walter S. Diehl, USN (Ret.) and Honorary Fellow of the Institute, Miss Diehl was employed as a Physicist and Aerodynamicist by the National Bureau of Standards in Washington. She was connected with the Fluid Dynamics Section.

After graduating from Western High School, Washington, Miss Diehl attended Smith College, where she majored in mathematics. She graduated with an A.B. degree in June, 1946. Miss Diehl also attended the National Bureau of Standards Graduate School. She was a member of the American Physical Society.

Miss Diehl lived with her parents at 4501 Lowell St., N.W., Washington.

Joseph Kapral

Joseph Kapral, TMIAS, an Aeronautical Engineer with the General Electric Company in Lynn, Mass., died on March 9. A graduate of St. Louis University, he was 28 years old and lived in North Reading, Mass. Mr. Kapral leaves his wife, Katherine.

NEWS OF MEMBERS

▸**Malcolm J. Abzug** (M), of El Segundo Division, Douglas Aircraft Company, Inc., has been appointed to the NACA's new Subcommittee on Automatic Stabilization and Control.

▸**E. Arthur Bonney** (M), of the Applied Physics Laboratory, The Johns Hopkins University, has been appointed to the NACA's new Subcommittee on Aerodynamic Stability and Control.

▸**Cyril H. Condon** (AM), Partner in the New York law firm of Condon & Forsyth, has been appointed to the New York State Bar Association's Committee on Aeronautical Law.

▸**George S. Graff** (AF), Chief of Aerodynamics, McDonnell Aircraft Corporation, is a member of the NACA's new Subcommittee on Aerodynamic Stability and Control.

(*Continued on page 84*)

Ten Years or More

Front row, left to right: Agnes Brewster, June, 1941; Ruth Meyers, October, 1943; Eve Krumm, August, 1945; Helen Nix, December, 1941; Concetta Valenti, October, 1945; Roslyn Lipner, February, 1943; Marjorie Rodé, March, 1941. *Second row:* Raymond Sterling, March, 1943; Thomas Meskel, October, 1945; Walter Wills, November, 1945; Lawrence Prezzano, October, 1945; George Bunatta, March, 1943; Robert Dexter, July, 1940; Leonard Rosenberg, November, 1943; Welman Shrader, April, 1943; John Glennon, July, 1941; Paul Johnston, April, 1946. *Third row:* Samuel Stern, February, 1946; Hugh Judge, August, 1940; Joseph Maitan, March, 1936.

Editorial

The First 289 Years Were the Hardest—

One of the (not so) bright and (very, very) trite remarks heard in almost any gathering of people who are enjoying the "benefits" of *middle* age (so-called) has to do with the seeming acceleration of the passage of time. The older one gets, the faster it goes (if we remember the standard expression correctly).

This one "clichéd" us right in the solar plexis the other day when the Lady-Who-Runs-Us (Marjorie Rodé by name) came up with the remark that come such-and-such a date (now past) she had had to put up with our idiosyncrasies for a period of 10 years. This seemed impossible on the face of it because (we said) the War ended only a couple of years ago, and we didn't get here until that was over. She said she didn't mean Korea (and mumbled something else about Lincoln and the Emancipation Proclamation), so we took a look at the calendar, and she was right. We came aboard just 10 years ago mid-April. This still seemed absurd, because we still feel among the junior members of the IAS staff—and again that turns out to be about right, as the following data will show.

We took a reading on IAS vital statistics and found that 21 of our staff of about 60 have served the Institute for well over 10 years! The breakdown shows 4 at 11 years; 2 at 12 years; 6 at 13 years; 4 at 15 years; two 16 year olds; and 1 (Joe Maitan, IAS Controller) 20 years. Three of the group, Bob Dexter, John Glennon, and Agnes Brewster, were associated with an IAS research project several years prior to their employment by the Institute.

Now this is quite a record. It is gratifying to those of us who manage, and it should be encouraging to those who belong. It points up the fact that your Institute has a stability and a continuity that is reflected in intelligent and experienced service to the membership. We doubt if any of the professional societies (many of which are considerably older than we are) can better this record, percentagewise.

We thought the membership should meet this group that has served the IAS so long. The pictures were taken on April 9. Total service of the group adds up to 289 years!

A ripe old age!

S.P.J.

IAS Pacific Aeronautical Library, Los Angeles. *Left:* Nell Steinmetz, October, 1944. *Right:* Carol Cunningham, November, 1944.

The physical basis of the area rule as well as applications to the interpretation, correlation, and improvement of drag-rise characteristics are considered.

Zero-Lift-Drag Characteristics of Wing-Body Combinations at Transonic Speeds

Richard T. Whitcomb*
Langley Aeronautical Laboratory, NACA

CONSIDERATION of the general physical nature of the flow at transonic speeds, together with comparisons of the flow fields and drag-rise characteristics for wing-body combinations and bodies of revolution, has led to the conclusion that near the speed of sound the drag rise for a thin low-aspect-ratio wing-body combination is primarily dependent on the axial distribution of cross-sectional area normal to the air stream.[1] (The drag rise, sometimes referred to as pressure drag, is the difference between the drag level near the speed of sound and the drag level at subsonic speeds where the drag is due primarily to skin friction.) In order to illustrate the concept, Fig. 1 shows a wing-body combination and a body of revolution. A typical cross section normal to the air stream for the wing-body combination is shown at AA. The cross-sectional area of the wing is wrapped around the body of revolution so that the body has the same cross-sectional area at BB. All the other cross-sectional areas of the body of revolution are the same as those for the wing-body combination at the same axial stations. On the basis of the conclusion just stated, the drag rise for this body of revolution should be similar to that for the wing-body combination. This relation may also be arrived at on the basis of the linear supersonic theory developed by Wallace D. Hayes.[2]

This relationship of the drag-rise increments for the wing-body combination and the comparable body of revolution is due primarily to the general similarities of the major portions of the extensive flow fields of the configurations These similarities are illustrated in Figs. 2 and 3 while present schlieren photographs of the flow fields for unswept- and sweptback-wing/body combinations, together with those for equivalent bodies of

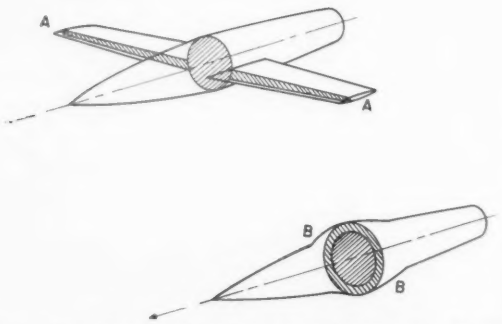


FIG. 1. Wing-body combination and equivalent body of revolution.

revolution. The combinations have been rolled to three positions so that side, plan, and intermediate views are seen. Near the edges of the pictures, the observed shocks for the combinations in each view are generally similar to those for the equivalent bodies. These comparisons are indicative of the similarities of the extensive fields beyond the view of the schlieren. Near the configurations there are differences of the flow fields for the wing-body combinations and equivalent bodies of revolution. However, the major portion of the energy losses associated with the shocks is produced in the extensive regions at appreciable distance from the configuration. Therefore, from a drag standpoint, it may be assumed that these differences near the configuration are of secondary importance. The general similarities of the extensive flow fields at distances from the configuration may be attributed to several aerodynamic phenomena characteristic of flow near the speed o sound:

(1) The field of any given displacement is concentrated in a plane nearly normal to the air stream. Because of this fact, the streamwise locations of the effects of the displacements of the wing are essentially the same as those for the corresponding effects produced by the comparable body of revolution.

(2) At these considerable lateral distances from the configuration, the field is primarily dependent on the

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general displacement of the configuration rather than on the details of the shape.

The generally close similarities of the effective fields for the wing-body combination and the comparable body of revolution in the regions producing the main portion of the shock losses suggest that the energy losses associated with the shocks for the two configurations should be similar. Since the drag rise for thin low-aspect-ratio wings is due primarily to shock losses, the drag rise for the combination should be approximately the same as that for the equivalent body of revolution.

In Fig. 4, the measured drag-rise increments for various swept-, delta-, and unswept-wing/body combinations and complete airplanes at a Mach Number of 1.03 are compared with the increments for equivalent bodies of revolution. The aspect ratios of the wings are 4 or less, and the thickness ratios are 7 per cent or less. Except for one configuration, there is a general qualitative agreement between these drag-rise increments. Deviations from exact agreement are due to second-order effects, such as differences of the flow fields as shown in Figs. 2 and 3. The single case of marked disagreement is for a swept-wing airplane configuration. A study of this configuration indicates this disagreement may be due to the magnitude of the trailing-edge sweep of the wing for this particular configuration. As would be expected, the correlation between the drag-rise increments of the wing-body combinations and the equivalent body of revolution generally becomes less close as the Mach Number is increased beyond 1.0. The severity of this divergence varies markedly depending on the configuration.

It would be expected on the basis of this concept that, near the speed of sound, the minimum drag rise would be obtained by designing a wing-body combination with an area distribution similar to that for a smooth body of revolution with the highest possible fineness ratio. The fineness ratio that should be used is probably considerably less than that required for minimum total drag because of such problems as airplane stability and structural weight. One method of obtaining this favorable area distribution is to reshape the body. A number of experiments have been made to determine the effectiveness of such reshaping. Representative results, obtained in the Langley 8-ft. transonic tunnel, are presented in Fig. 5.

On the left-hand side of this figure are shown the effects of such a body modification on the zero-lift drag-rise characteristics of a 6 per cent thick, aspect ratio 4, 45° swept-wing/body combination. The solid line shows the variation of drag for the wing in combination with a body of revolution of fineness ratio of 11. The wing is placed on the body in such a manner that the leading edge of the wing is at the maximum diameter of the body. With this arrangement, the indentation used did not change the maximum cross-sectional area of the body. The dashed lines are the results obtained for the wing in combination with a body of revolution indented circularly to obtain the same area distribution as for the original body alone. For comparison, the re-

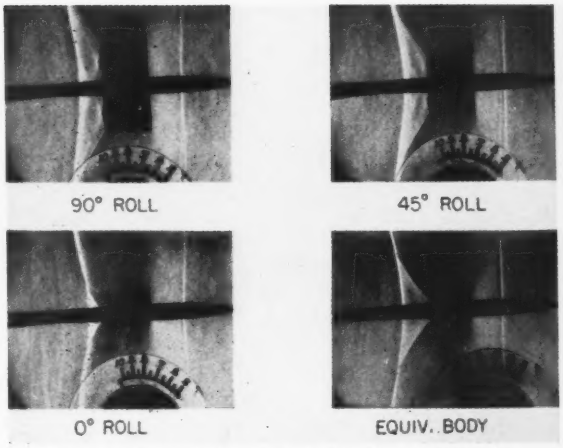

FIG. 2. Transonic flow past body with straight wing.

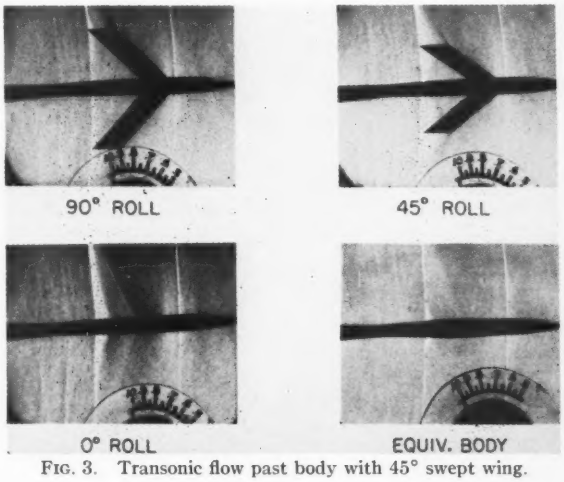

FIG. 3. Transonic flow past body with 45° swept wing.

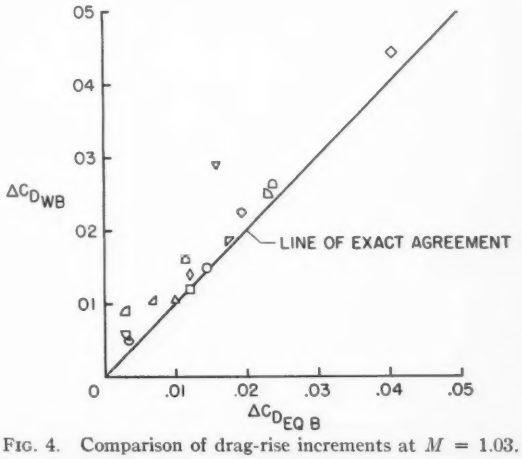

FIG. 4. Comparison of drag-rise increments at $M = 1.03$.

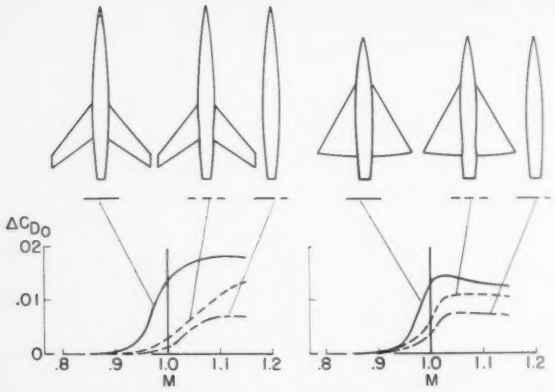

FIG. 5. Effect of body indentation on transonic drag rise.

sults for the body alone are also shown. Indentation eliminated approximately 90 per cent of the drag rise associated with the wing at Mach Numbers from 1.00 to 1.05. When the Mach Number is increased beyond 1.05, the drag rise for the indented wing-body combination approaches that for the original wing-body combination.

On the right-hand side of Fig. 5 are presented the effects of body indentation on the zero-lift drag-rise characteristics for a 4 per cent thick, 60° delta-wing/body combination. The solid curve shows the drag characteristics for the wing in combination with a body of revolution having a fineness ratio of 7.5. The dashed line indicates the drag variation after the body has been indented circularly to produce an area distribution for the combination the same as that for the original body alone. In this case, the indentation reduced the maximum cross-sectional area of the body somewhat. It may be noted that again a significant reduction in the drag rise was obtained by such an indentation at transonic speeds. However, in this case, the drag rise for the indented wing-body combination is significantly greater than that for the body alone. This deviation from the result which might be expected on the basis of the area-distribution concept is probably due to the fact that the body required to obtain the smooth area distribution of the combination had a rather abrupt change in shape near the trailing edge of the wing. This shape probably led to severe local velocity gradients. Since the proper functioning of the body fields in offsetting the drag of the wing depends to a great extent on the velocity gradients being small, it might be expected that these severe gradients would lead to an incomplete reduction in drag. Also, near the speed of sound, a shock was present over this corner and may have caused some separation at this point which would not be expected on the original body alone. It is probable that a further reduction in drag could have been obtained at transonic speeds by smoothing the contour of the body slightly Similar reductions in drag near the speed of sound have been obtained by body indentation for other delta and unswept wings.

Results obtained with smooth-surfaced configurations have indicated a marked reduction in drag at subsonic speeds associated with the use of indentation with swept and delta wings. However, with fixed transition this difference is not present. The influence of surface conditions on the effects of indentation apparently decreases with increase in the Mach Number to supersonic speeds. The drag rises at lift coefficients to approximately 0.4 are reduced by about the amounts shown for zero lift. At higher lift coefficient, the improvements decrease gradually. Obviously, the volume of the indented wing-body combination is not as great as that for the original wing-body combination. However, increasing the size of the body to recover the volume lost in indentation would increase the drag for the indented combination by a small fraction of this reduction in drag obtained.

The question now might arise as to whether it would be possible to obtain drag reductions at transonic speeds by adding to an existing wing-body combination to obtain a more favorable area distribution. Recently, investigations have been made of such additions on a 60° delta-wing configuration. Results are presented in Fig. 6. First, the fuselage was extended approxi-

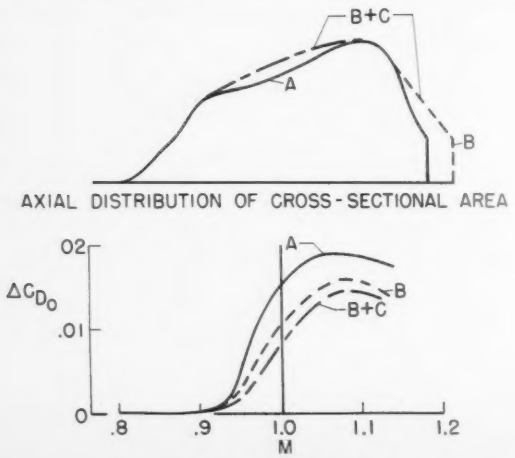

FIG. 6. Effect of additions to body.

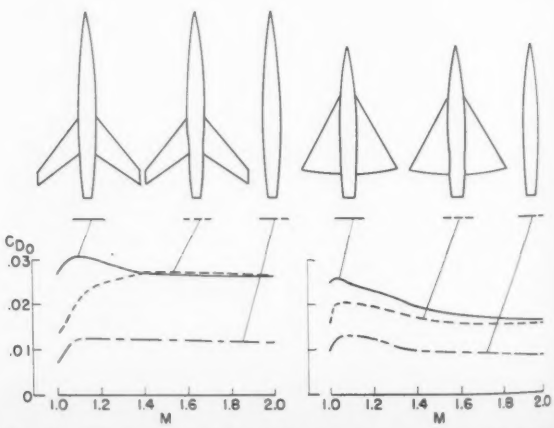

FIG. 7. Effect of body indentation on supersonic zero-lift drag.

mately 8 per cent to obtain a more favorable area distribution of the rearward portion of the configuration. This addition resulted in significant reductions in the drag rise. Further reduction was obtained by adding side fairings to the extended configuration to fill the dip in the area distribution as shown. The body lines with these additions were still relatively smooth. Additions which lead to severely irregular body lines would not be recommended.

The effects of the changes in body shape on the total drag coefficients at Mach Numbers up to 2.0 are shown in Fig. 7. The configurations are the same as those shown in Fig. 5. The results for Mach Numbers above 1.15 were obtained in the Langley 4- by 4-ft. supersonic pressure tunnel. For the swept-wing/body combination, body indentation had little effect on the drag at Mach Numbers from 1.4 to 2.0. For the delta-wing/body combination, body indentation reduced the drag at all Mach Numbers up to 2.0, but by a progressively smaller amount. The fact that reductions were obtained at these supersonic speeds indicates that to a certain extent the factors affecting drag at moderate supersonic speeds may be similar to those for transonic speeds for low-aspect-ratio thin wings such as this one.

The effect of external nacelles on the transonic drag rise may also be interpreted on the basis of the area-rule concept. This is illustrated by the experimental results presented in Fig. 8. Symmetrically mounted nacelles were investigated by the Pilotless Aircraft Research Division at a number of spanwise locations on a 45° swept wing with an aspect ratio of 6 and a thickness ratio of 6 per cent. The drag-rise characteristics are shown on the left of the figure; the axial developments of cross-sectional area are shown on the right. The highest transonic drag was obtained with the nacelle position giving the highest maximum area and greatest rates of change of area. The drag rise is progressively reduced with improvements in the area development. For the tip location of the nacelle, a favorable effect on drag was measured. This effect may be attributed to the lengthening of the total area

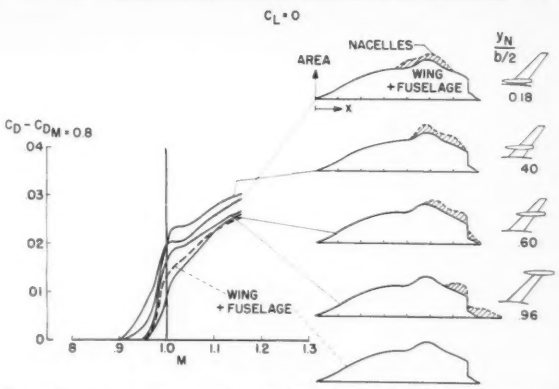

FIG. 8. Drag of spanwise series of symmetrically mounted nacelles.

development with the associated reduction of the rates of change of area along the aft portion of the configuration.

In conclusion, the results presented have shown that, near the speed of sound, the drag rise for a low-aspect-ratio thin wing/body configuration is generally a function of the axial distribution of cross-sectional area normal to the air stream. By using this relationship, it is possible to reduce greatly the drag rise of the conventional wing-body combinations by redesigning the fuselage to produce a smooth axial distribution of area for the combination. The resulting reshaped fuselage of the combination should not have abrupt changes in contour. Of course, to obtain the lowest possible drag coefficients, the fineness ratio of the equivalent body should be sufficiently high. Also, the effects of external nacelles on the drag rise are correlated qualitatively, at least, on the basis of the area rule.

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[1] Whitcomb, Richard T., *A Study of the Zero-Lift Drag-Rise Characteristics of Wing-Body Combinations Near the Speed of Sound*, NACA RM L52H08, 1952.

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A review of the essential functional features of geometrical stabilization systems and a description of the performance characteristics of gyro units used in these systems.

The Floating Integrating Gyro and Its Application to Geometrical Stabilization Problems on Moving Bases*

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Introduction

Geometrical stabilization is the process of maintaining a desired orientation of a *stabilized entity* with respect to a selected system of reference coordinates. For example, if the stabilized entity is an airplane and the selected reference coordinates are fixed to the earth, geometrical stabilization exists when the wings remain continuously level and the fuselage direction has a constant azimuth. This result depends on the operation of some mechanism that provides a *reference member* capable of holding a definite orientation with respect to the selected external reference coordinates, without being affected by rotational or linear movements of the structure that supports the mechanism. The index bar of a modern bank-and-climb flight indicator is an example of such a reference member. This bar holds substantial parallelism with the horizon, no matter how the aircraft that carries the indicator may maneuver. With the index bar available as an indication of the horizon, a human pilot or an automatic flight control system has the information necessary to work the elevators and ailerons so that the fuselage and wings are held at desired angles with respect to the horizontal plane.

The reference member of a geometrical stabilization system must be unaffected by movements of the support-providing structure and, in addition, must be capable of responding to input *command signals*†† by moving with respect to external reference coordinates. For example, the reference member of a conventional aircraft turn indicator is a divided circle that holds a set direction with respect to the earth—independently of airplane motion—except when it is caused to change its orientation by signals from a magnetic field direction indicator or when it is reset by a human operator.

This article reviews the essential functional features of geometrical stabilization systems and describes the performance characteristics of gyro units that are used in systems of this kind. Special attention is given to gyro units that are capable of

(1) Sensing the angular deviation of a reference member from a reference orientation.

(2) Receiving input signals that command changes in the reference orientation.

The general functional features of integrating gyro units designed at the Instrumentation Laboratory, Massachusetts Institute of Technology, to meet these performance requirements are described. These units obtain gimbal support without appreciable friction by utilizing the principle of flotation. In addition, methods for testing gyro units of various types are discussed, and performance characteristics for typical units are given.

Inertial Space

Any geometrical framework in which a body free from all applied forces is without acceleration has the essential property of a space in which Newton's Law of Inertia is valid. For this reason, such a space is called

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†† By definition, a command signal for any operating unit is some physical quantity that carries information to the unit on the action the unit must take in performing its essential functions. The command signal causes the unit to carry out this action by virtue of the design and construction of the system involved.

inertial space. All particles of matter tend to hold their directions of motion with respect to inertial space. As a result, any rigid body spinning about an axis of symmetry holds the direction of the spin axis fixed with respect to inertial space, unless a torque is applied to the body about some line not identical with the spin axis. When such a torque is applied, the spinning body rotates about an axis that is at right angles to both the spin axis and the axis about which the torque is applied. This behavior characteristic of spinning rotors—namely *directional* change in response to a torque—is called *gyroscopic action.* In practice, gyroscopic action makes it possible to design self-contained stabilization equipment that uses inertial space as the reference space. Because no mechanical or radiation connection is required between the equipment and the reference framework, geometrical stabilization and orientational control systems are often based on inertial reference coordinates. The conventional gyroscopic flight instruments, the ship-borne stable unit, and the marine gyroscopic compass are examples in support of this statement.

Gyroscopic Action

Gyroscopic action is due to the tendency of a spinning wheel to hold the orientation of its plane of rotation fixed with respect to inertial space. When a torque is applied to the wheel, Newton's Second Law of Motion requires an increase of angular momentum* about the axis around which the torque is applied. Therefore, when the usual situation of constant angular velocity for a gyroscopic rotor exists, the only way the spinning rotor can respond to an applied torque is by turning its spin axis toward the torque axis. The corresponding angular velocity is called *precession* and has a magnitude proportional to that of the torque and inversely proportional to that of the angular momentum of the rotor.† Precession is easily demonstrated by means of a spinning rotor supported by a double gimbal system to give its spin axis two degrees of freedom in rotation. A similar arrangement is widely applied in gyroscopic instruments where a gimbal holding a spinning rotor is used as the reference member.

Two Degree of Freedom Gyro Unit

The two degree of freedom gyro unit has the properties required of a mechanism to provide a reference member that is stabilized with respect to inertial space. The function of causing the reference member to rotate with respect to inertial space in response to input command signals may be added to the unit by means of devices for applying controlled torques to the gyro rotor. Information on the angular deviation of a datum line fixed to the gyro unit case relative to the spin axis of the rotor may be made available by signal generators acting between the reference member and the case of the unit.

Fig. 1 is an illustrative diagram showing the essential features of an angular deviation—orientational control signal receiving system based on the two degree of freedom gyro unit. The spin axis fixed to the inner gimbal gives the *indicated reference orientation.* Two potentiometer-type signal generators furnish electrical voltages that represent the two components of the angular deviation of a datum line fixed to the case (this line is not shown in Fig. 1) from alignment with the indicated reference orientation. For small magnitudes,‡ these deviation components are measured as angles about the inner gimbal reference axis and the outer gimbal reference axis. Two torque generators, one acting about the outer gimbal reference axis and the other acting about the axis of a bail connected to the inner gimbal, make it possible to apply precessing torques to the gyro rotor. By means of command inputs to the torque generators, the indicated reference orientation may be rotated toward any desired *command reference orientation.*

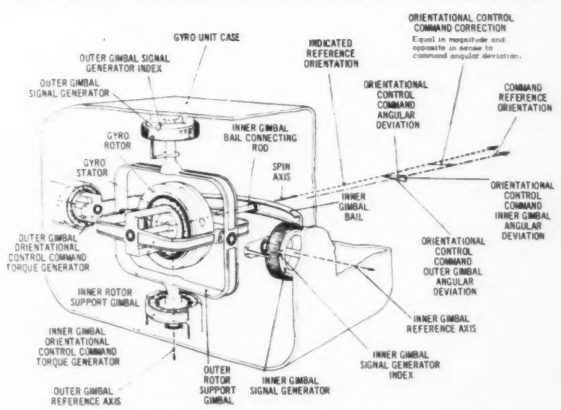
It is usual practice to mount the gyro unit on some structure whose direction is to be adjusted and use the signal generator voltages as inputs to the controls associated with the structure so as to keep the case datum direction aligned with the indicated reference orientation.** With this arrangement, the orientation of the structure may be changed at will by supplying

* By definition, the angular momentum of a rotor spinning about an axis of symmetry is the product of the moment of inertia of the rotor about the spin axis and the angular velocity of the rotor.

† Gyroscopic theory is discussed in references 1 through 28.

‡ Units with the features shown in Fig. 1 are usually applied to situations in which the angular deviations represented by the signals are restricted to small magnitudes.

** The condition in which the case datum direction is aligned with the indicated reference orientation is indicated by the signal generator outputs going to their minimum levels, which are often called *nulls.* Physically, this situation exists when the potentiometer sliders are aligned with the signal generator indices.


ORIENTATIONAL CONTROL COMMAND CORRECTION
Equal in magnitude and opposite in sense to command angular deviation.
GYRO UNIT CASE
INDICATED REFERENCE ORIENTATION
OUTER GIMBAL SIGNAL GENERATOR INDEX
OUTER GIMBAL SIGNAL GENERATOR
ORIENTATIONAL CONTROL COMMAND ANGULAR DEVIATION
COMMAND REFERENCE ORIENTATION
GYRO ROTOR
INNER GIMBAL BAIL CONNECTING ROD
GYRO STATOR
SPIN AXIS
INNER GIMBAL BAIL
ORIENTATIONAL CONTROL COMMAND INNER GIMBAL ANGULAR DEVIATION
OUTER GIMBAL ORIENTATIONAL CONTROL COMMAND TORQUE GENERATOR
ORIENTATIONAL CONTROL COMMAND OUTER GIMBAL ANGULAR DEVIATION
INNER ROTOR SUPPORT GIMBAL
INNER GIMBAL REFERENCE AXIS
INNER GIMBAL ORIENTATIONAL CONTROL COMMAND TORQUE GENERATOR
INNER GIMBAL SIGNAL GENERATOR INDEX
OUTER ROTOR SUPPORT GIMBAL
INNER GIMBAL SIGNAL GENERATOR
OUTER GIMBAL REFERENCE AXIS

Notes: 1. Gyro units with the general features shown in the illustrative diagram of this figure are commonly used in automatic pilots for aircraft.
2. The range of satisfactory operation for a unit of this kind is restricted to indicated angular deviation magnitudes of small size, i.e., to angles of less than five degrees.

FIG. 1. Pictorial diagram of an illustrative two degree of freedom gyro unit with the essential features of a two-axis angular deviation - orientational control signal receiving system.

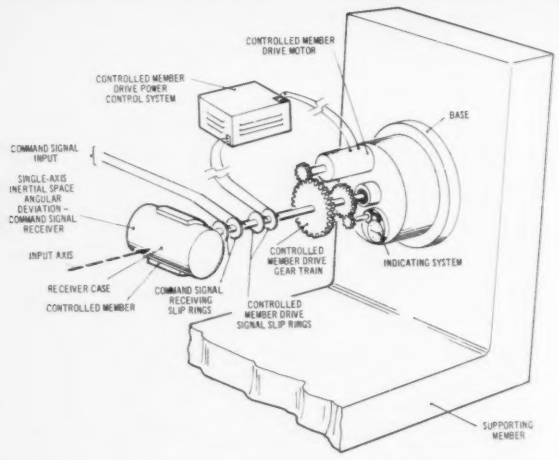
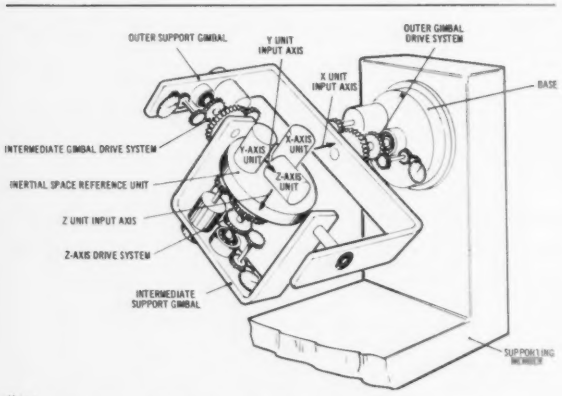


FIG. 2. Pictorial diagram of a single-axis inertial space rotation integrator based on a single-axis inertial space angular deviation - command signal receiver with a servodriven controlled member.

command inputs to the torque generators so that the gyro spin axis is forced to precess toward the command reference orientation. The structure will follow this rotation because of the constraint exercised by its associated controls, which causes it to move with the spin axis direction. A typical example in which a two degree of freedom gyro unit is used in a control arrangement of this type is the turn-gyro subsystem of a conventional autopilot for aircraft. In this application, the gyro unit and the control components cause the airplane carrying the equipment to align its fuselage axis with an indicated reference orientation that may be changed by command inputs from any source.

Inertial Space Angular Velocity Integrators

Both geometrical stabilization and response to orientation control signals, as these phases of behavior are illustrated by the gyro unit of Fig. 1, are aspects of a single performance characteristic that is fundamentally *inertial space angular velocity integration*. Devices having this property receive input signals and produce angular velocity output components with respect to inertial space that are proportional to the input signals. This means that, starting from any given orientation, the reference member involved will rotate with respect to inertial space through an angle that is proportional to the time integral of the corresponding input signal. It is important to note that no "natural" angular position references exist in inertial space. References of this kind must be artificially established by starting angular velocity integration from some arbitrary reference position of the member whose angular velocity with respect to inertial space is controlled by the input signal.



Notes:
1. Electrical slip rings, connections, and resolvers are omitted from this figure.
2. The input axis for any receiver unit is the single direction fixed to the case of the unit about which it is sensitive to rotation with respect to inertial space.
3. The X-axis unit is a single-axis inertial space angular deviation – command signal receiver with its input axis along X.
4. The Y-axis unit is a single-axis inertial space angular deviation – command signal receiver with its input axis along Y.
5. The Z-axis unit is a single-axis inertial space angular deviation – command signal receiver with its input axis along Z.

FIG. 3. Pictorial diagram of a three-axis inertial space rotation integrator based on three single-axis inertial space angular deviation - command signal receivers with servodrives for the three gimbal axes.

Single-Axis Servodriven Angular Velocity Integrator

Fig. 2 shows the essential features of a single-axis inertial space angular velocity integrator in which a single-axis angular deviation - command signal receiver is fixed to a controlled member that is servodriven with respect to a base. The function of the servo is to drive the controlled member at the angular velocity necessary to keep the output signal from the receiver at some small magnitude.* When no input signal goes to the receiver, the system will give geometrical stabilization in the sense that the servo will cause the controlled member to have zero angular velocity about the input axis with respect to inertial space, no matter how the base may rotate about the input axis. By the use of sufficient power in the servomotor, interference with stabilization because of imperfect bearings and other mechanical effects in the driven system may be reduced to tolerably small levels. When an input signal is supplied to the receiver, the corresponding receiver output signal causes the servo to change its driving rate until the controlled member angular velocity is proportional to the input signal. Under these circumstances, the angle turned through by the controlled member with respect to inertial space is proportional to the time integral of the input signal, and the system is operating as a space integrator.

Three-Axis Servodriven Space Integrator

Fig. 3 shows the general features of a three-axis servodriven platform that is based on the use of an *inertial space reference unit* carrying three single-axis angular deviation - command signal receivers. A vertical-seeking unit can be constructed by adding the necessary resolvers and signal generators to the system of

* In a system having more than one integration in the controlled member drive power control system, the output signal may actually become zero for any constant angular velocity of the controlled member, under normal operating conditions.

Fig. 3 and by including accelerometers to supply monitoring command signals for the receivers. The addition of a North-sensing unit, such as a compass, to give command signals offers the possibility of realizing directional information from the three-axis platform arrangement.

Single Degree of Freedom Gyro Units as Angular Deviation - Command Signal Receivers

A servodriven space integrator operates from signals that represent angular deviations of an inertial space reference unit from the reference orientation for this unit. The most generally useful form of the space integrator has three degrees of freedom and therefore requires three angular deviation signals. These three signals might be provided by two, two degree of freedom gyro units with the features shown in Fig. 1. Because each unit of this kind has the capability of producing a pair of deviation signals for a pair of corresponding orthogonal axes, it follows that two units provide the possibility of four deviation signals where only three are required. This fact suggests that the use of three identical angular deviation receivers, each working about a single axis, can give a more desirable three-axis integrator system configuration than a design that uses two, two degree of freedom units. For example, in the special instance of the single-axis space integrator of Fig. 2, it is obvious that a two degree of freedom gyro unit would be unnecessarily complicated if a single-axis angular deviation - command signal receiver of less complex construction were available. The essential change required to convert the two degree of freedom gyro arrangement into a unit insensitive to rotational components except those associated with a single input axis* is the suppression of one degree of freedom in the gimbal system. This suppression of one axis of response in a two degree of freedom gyro unit results in design simplifications that lead to smaller units with higher performance than is possible with two degree of freedom units.

Single-axis gyro units are classified into two distinct types, depending on the nature of the output signal corresponding to an angular velocity of the gyro unit case about its input axis:

(1) The *rate gyro unit*, which gives an output signal proportional to the input angular velocity of the case with respect to inertial space.

(2) The *integrating gyro unit*, which gives an output signal proportional to the time integral of the input angular velocity of the case with respect to inertial space. This means that the changes in the output signal are proportional to the changes in the orientation of the case about the input axis with respect to an inertial space reference.

The next two sections describe the essential features of the single-axis rate gyro unit and the single-axis integrating gyro unit. In order to show the relationships of these units to the two degree of freedom gyro unit, illustrative diagrams are drawn as modifications of the diagram of Fig. 1.

* In practice, single-axis receivers will respond to some extent to rotation about axes other than the input axis. In properly designed and applied units, the degree of this response will be very small.

Single-Axis Rate Gyro Unit

The elements of the single-axis rate gyro unit appear when

(1) One degree of freedom is removed from the two degree of freedom arrangement of Fig. 1 by fixing the outer gimbal to the case.

(2) Means are provided for an elastic restraint torque to act about the remaining free gimbal axis.

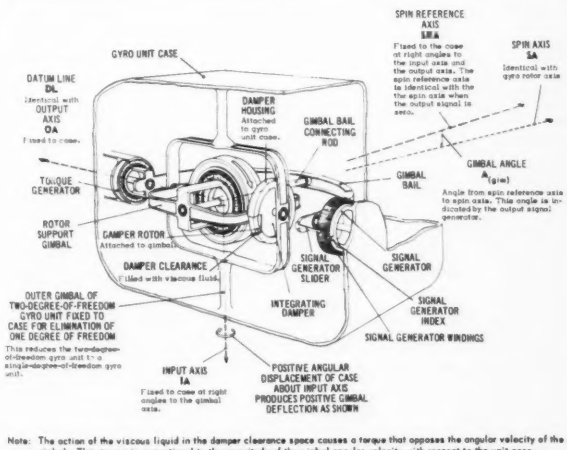
(3) A damper is added to suppress spurious oscillations.

Fig. 4 shows the features of a rate gyro unit in terms of modifications† to the illustrative pictorial diagram of Fig. 1. When the unit of Fig. 4 is rotated with respect to inertial space about the former outer gimbal axis, the gyro rotor exerts a torque‡ against the restraints that act about the inner gimbal axis (which may now be called the gimbal axis since there is now only one active gimbal). This torque is the essential output of the gyro rotor. The torque exists because of the tendency of the rotor to turn toward an axis about which the spin axis is forced to rotate.** The direction

† The details shown in Fig. 4 are illustrative only and are intended to stress the differences between a two degree of freedom gyro unit and a rate gyro unit. No actual unit would be designed with the details of construction thus portrayed. In addition, the torque generator shown is not usually a part of a single-axis rate gyro unit; it is included in Fig. 4 in order to retain continuity with Figs. 1 and 5.

‡ The term *torque* used in this connection is to be interpreted as being the negative of the rate of change of the angular momentum due to the rotation in space of the axis of the spinning rotor.

** In proper applications of rate gyro units, these units are attached to supporting members relatively so large and turned by a source of torque so great that the reaction torque of the gyro unit during periods of changing angular velocity has a negligible effect on the motion of the supporting member.


SPIN REFERENCE AXIS
SRA
Fixed to the case at right angles to the input axis and the output axis. The spin reference axis is identical with the the spin axis when the output signal is zero.
SPIN AXIS
SA
Identical with gyro rotor axis
GYRO UNIT CASE
DATUM LINE
DL
Identical with OUTPUT AXIS
OA
Fixed to case.
DAMPER HOUSING
Attached to gyro unit case.
GIMBAL BAIL CONNECTING ROD
GIMBAL ANGLE
$A_{g(m)}$
Angle from spin reference axis to spin axis. This angle is indicated by the output signal generator.
TORQUE GENERATOR
GIMBAL BAIL
ROTOR SUPPORT GIMBAL
DAMPER ROTOR
Attached to gimbal
DAMPER CLEARANCE
Filled with viscous fluid.
SIGNAL GENERATOR SLIDER
SIGNAL GENERATOR
OUTER GIMBAL OF TWO-DEGREE-OF-FREEDOM GYRO UNIT FIXED TO CASE FOR ELIMINATION OF ONE DEGREE OF FREEDOM
This reduces the two-degree-of-freedom gyro unit to a single-degree-of-freedom gyro unit.
INTEGRATING DAMPER
SIGNAL GENERATOR INDEX
SIGNAL GENERATOR WINDINGS
INPUT AXIS
IA
Fixed to case at right angles to the gimbal axis.
POSITIVE ANGULAR DISPLACEMENT OF CASE ABOUT INPUT AXIS PRODUCES POSITIVE GIMBAL DEFLECTION AS SHOWN

Note: The action of the viscous liquid in the damper clearance space causes a torque that opposes the angular velocity of the gimbal. This torque is proportional to the magnitude of the gimbal angular velocity with respect to the unit case.

FIG. 4. Pictorial diagram of an illustrative single-axis angular velocity receiver based on the single degree of freedom gyro unit with elastic restraint and an oscillation control damper; the single-axis rate gyro unit.

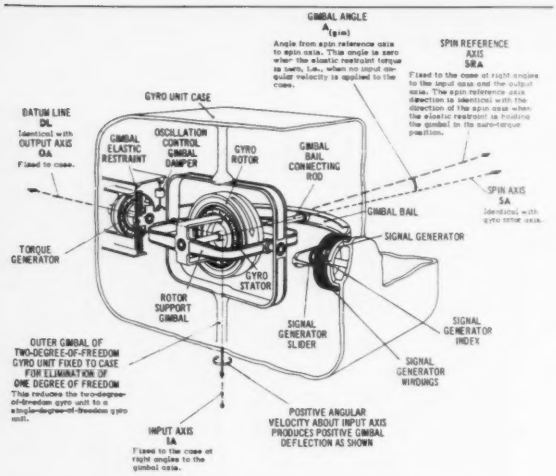

GIMBAL ANGLE
A
(φ=0)
Angle from spin reference axis to spin axis. This angle is zero when the elastic restraint torque is zero, i.e., when no input angular velocity is applied to the case.
SPIN REFERENCE AXIS
SRA
Fixed to the case at right angles to the input axis and the output axis. The spin reference axis direction is identical with the direction of the spin axis when the elastic restraint is holding the gimbal in its zero-torque position.
GYRO UNIT CASE
DATUM LINE
DL
Identical with OUTPUT AXIS OA
Fixed to case.
GIMBAL ELASTIC RESTRAINT
OSCILLATION CONTROL GIMBAL DAMPER
GYRO ROTOR
GIMBAL BAIL CONNECTING ROD
SPIN AXIS
SA
Identical with gyro rotor axis.
GIMBAL BAIL
SIGNAL GENERATOR
TORQUE GENERATOR
GYRO STATOR
ROTOR SUPPORT GIMBAL
SIGNAL GENERATOR SLIDER
SIGNAL GENERATOR INDEX
SIGNAL GENERATOR WINDINGS
OUTER GIMBAL OF TWO-DEGREE-OF-FREEDOM GYRO UNIT FIXED TO CASE FOR ELIMINATION OF ONE DEGREE OF FREEDOM
This reduces the two-degree-of-freedom gyro unit to a single-degree-of-freedom gyro unit.
INPUT AXIS
IA
Fixed to the case at right angles to the gimbal axis.
POSITIVE ANGULAR VELOCITY ABOUT INPUT AXIS PRODUCES POSITIVE GIMBAL DEFLECTION AS SHOWN

FIG. 5. Pictorial diagram of an illustrative single-axis angular deviation - command signal receiver based on the single degree of freedom gyro unit with an integrating damper; the single-axis integrating gyro unit.

of this turning* of the spin axis is such that, if all restraining torques were removed, the rotor would end up spinning about the axis of the forced rotation of the case, with its spin in the same direction as the case rotation. The gimbal axis is called the *output axis* because it is the axis about which the output torque of the rotor is applied to the restraints. The *spin reference axis* is the direction fixed to the case that is identical with the direction of the spin axis† when the gyro unit is not turning with respect to inertial space so that the elastic restraint holds the gimbal in its zero-torque position.‡ The *input axis* is the direction fixed to the case at right angles to the output axis and the spin reference axis. The positive sense of the input axis is chosen so that it completes a right-handed set of axes, in the order of output axis, spin reference axis, and input axis. When the angle of the spin axis with respect to the spin reference axis is substantially zero, the input axis is the only direction about which an angular velocity of the case with respect to inertial space will cause the gyro rotor to produce an output torque.

When the rate gyro unit is given a constant angular velocity about the input axis, so that static conditions** exist, the rotor output torque causes the spin axis to tip away (precess) from the spin reference axis, with the result that the elastic restraint force due to the spring acting at the end of an arm applies a reaction torque to the gimbal. This torque acts in the proper direction to cause the spin axis to precess toward the axis about which the elastic restraint torque is applied—that is, the output axis. This precession takes place with respect to inertial space about the input axis and is in the direction of the input angular velocity. Static equilibrium exists when the elastic restraint torque precesses the spin axis at a rate just equal to the angular velocity with which the case is being forced to rotate about the input axis. In this situation, the gimbal angle is proportional to the applied torque required to balance the output torque of the gyro rotor, which in turn is proportional to the input angular velocity. When the signal generator is properly adjusted so that its output is zero†† with the gimbal angle at zero, the signal from the unit will be a direct indication of the input angular velocity.‡‡

SINGLE-AXIS INTEGRATING GYRO UNIT

A single-axis integrating gyro unit is obtained when the single-axis rate gyro unit shown in Fig. 4 is modified as follows:

(1) The elastic restraint is eliminated.

(2) The damping is made relatively heavy so that it acts as the primary restraining torque instead of being only strong enough to control undesirable oscillations.

The essential features of such a unit are illustrated in Fig. 5, which is drawn as a modification of Figs. 1 and 4.

When the unit is given a constant angular velocity about the input axis with respect to inertial space, the gyro rotor exerts a torque of proportional magnitude on the gimbal about the output axis. Under static conditions§ and with zero input signal to the torque generator, the gyro rotor output torque is balanced by the torque generated by shear in the viscous fluid that fills the clearance space between the damper rotor and the damper housing. With a fluid having proper viscosity

* This turning of the spin axis toward the torque axis is simply the precession that is a basic characteristic of gyroscopic action.

† The positive direction of the spin axis as shown by the arrowhead in Fig. 4 is such that the rotor spins clockwise as seen by an observer looking along the spin arrow toward the arrowhead.

‡ The elastic restraint will hold the gimbal in its zero-torque position only when other torque components (such as—for example—those due to bearings) collectively sum to zero.

** Under static conditions, acceleration and damping torque components are both zero because they exist only when the gimbal angle is varying. A detailed discussion of dynamic effects is given in Fairchild Publication Fund Paper No. FF-13.

†† Because of electrical interference effects and the always somewhat imperfect matching of the signal generator zero with the elastic restraint zero, the output signal never actually goes to zero. The signal does pass through a *null* level, however, which is the level of the minimum signal that occurs as the gimbal angle passes through alignment with the spin reference axis.

‡‡ This proportionality holds only when the signal generator itself has a linear performance characteristic and the gimbal deflection angle never exceeds small magnitudes. As the gimbal angle is allowed to become larger, the unit has an increasing sensitivity to angular velocity about the spin reference axis. This so-called *coupling effect* is discussed in Fairchild Publication Fund Paper No. FF-13.

§ For the situation under discussion, static conditions exist when the gyro unit case has a constant angular velocity about the input axis with respect to inertial space and the gimbal has a constant angular velocity with respect to the case (within a limited range of gimbal deflection). This implies that the case angular velocity is considered to be the input and the rate of change of the signal from the unit is considered to be the output. As distinguished from static conditions, dynamic conditions exist when there is a changing angular velocity input and/or voltage rate output. The behavior of the single-axis integrating gyro unit under dynamic conditions is discussed in Fairchild Publication Fund Paper No. FF-13.

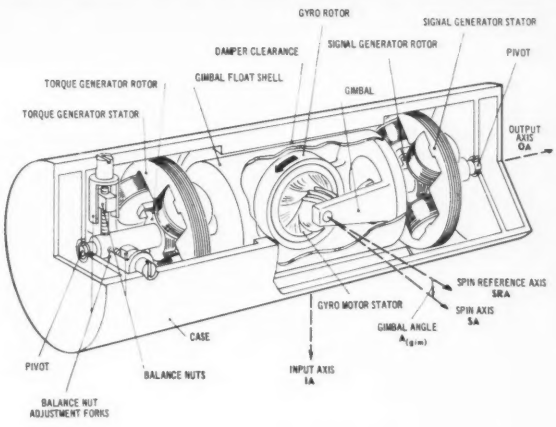
characteristics,* the balancing torque will be proportional to the angular velocity of the gimbal with respect to the case of the unit. Because the output torque from the gyro rotor is proportional to the angular velocity of the case about the input axis with respect to inertial space and the equal balancing torque is proportional to the angular velocity of the gimbal with respect to the case, it follows that the gimbal angular velocity is proportional to the input angular velocity of the case. With a signal generator having linear characteristics, this means that the rate of change of the output signal is proportional to the angular velocity input. A relationship of this type corresponds to an integration of the input angular velocity by the unit so that, starting from some orientation with the output signal at a selected reference level, the change in the output signal is proportional to the angular displacement of the case about the input axis from the position occupied by the case when the output signal was at its reference level.

When a command is applied by means of the torque generator, the gyro unit integrates the *difference* between the equivalent command angular velocity torque from the torque generator and the actual angular velocity torque from the gyro rotor.

Like rate gyro units, integrating gyro units should operate with the output signal near its null level so that the spin axis is constrained to remain substantially parallel to the spin reference axis. Since the integrating gyro unit has no inherent null-restoring property, it is necessary that it be used as a component in a servosystem that operates to drive the gimbal angle toward zero by rotating the case of the unit about the input axis or by supplying signal current to the torque generator.

Design Features of a Single-Axis Integrating Gyro Unit

Fig. 6 illustrates the essential features of a single-axis integrating gyro unit developed by the Instrumentation Laboratory, M.I.T. The electric-motor-driven gyro rotor is mounted in a hermetically sealed cylindrical chamber that carries pivots of the type used in watches. These pivots are fixed to the cylinder by means of projections along the axis of symmetry. The cylinder is designed to give the complete assembly substantially perfect flotation in a high-density, high-viscosity fluid that is contained in the clearance volume between the case and the cylinder. Because the weight of the cylinder is supported almost completely by pressure gradients in the fluid, the pivots are required to carry only extremely small loads in order to keep the float properly centered within the case. The resulting pivot-friction torque components are so small as to be effectively negligible for the purposes of operation. At the same time, the fact that supporting forces are transferred to the float by pressure gradients in the fluid, rather than



Note: The volume between the outside of the float and the inside of the case is completely filled with a fluid having the property of Newtonian viscosity; that is, the coefficient of viscosity is independent of shear gradient.

FIG. 6. Illustrative pictorial diagram for a single-axis integrating gyro unit (single-axis angular deviation - command signal receiver).

by stress concentrations in pivot material, means that the negligibly small pivot-friction level is accompanied by a great ability of the unit to withstand shock and vibration disturbances without mechanical damage or degradation of performance.

In addition to giving buoyancy support for the float, the fluid also provides the viscous shear resistance torque that causes the angular velocity of the gimbal with respect to the case to be proportional† to the gyro rotor output torque. The clearance between the outer surface of the float and the inner surface of the case is restricted by design to a magnitude of a few thousandths of an inch so that, with the motion encountered in operation, the source of torque acting on the gimbal is almost perfect viscous shear drag in the fluid layer. In addition, the fluid is selected to have a coefficient of viscosity that is constant for all shear rates of practical interest. By paying attention to this factor and using careful designs of the float, case, and fluid combination, the integrating action can be made substantially perfect over a wide range of input angular velocities.

Thermal control for the gyro unit must be provided in practical applications by some means external to the unit itself. This thermal control is required for three reasons:

(1) The density of the fluid with respect to the average density of the float and, consequently, the residual pivot load are adjusted by the average temperature of the unit. This adjustment is the primary function of temperature control.

(2) The effective viscosity of the fluid and, consequently, the integrating action of the system are controlled by the average temperature of the unit. In practical applications, gyro units are associated with servo arrangements in such a way that changes of integrating action affect only loop gains that have fairly

*For satisfactory operation, the damping fluid must have Newtonian characteristics—that is, the coefficient of viscosity must be independent of the shear gradient.

†Strictly speaking, this proportionality exists only under static conditions. Dynamic effects are discussed in Fairchild Publication Fund Paper No. FF-13.

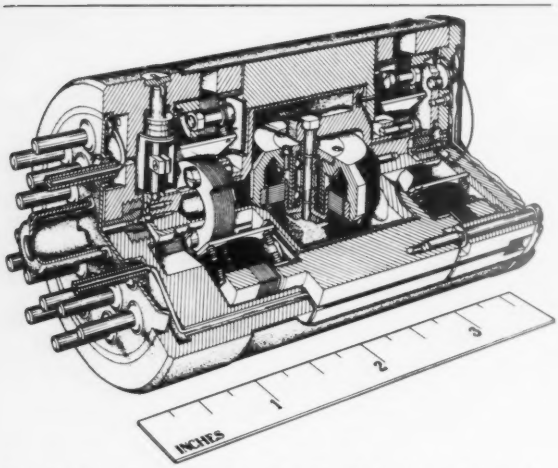


FIG. 7. Sectioned view of the M.I.T. 10[4] single-axis integrating gyro unit.

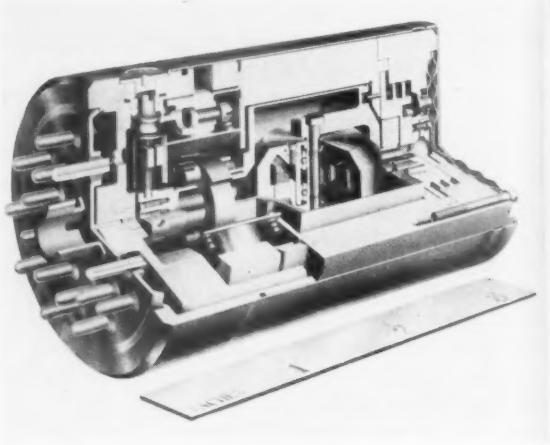


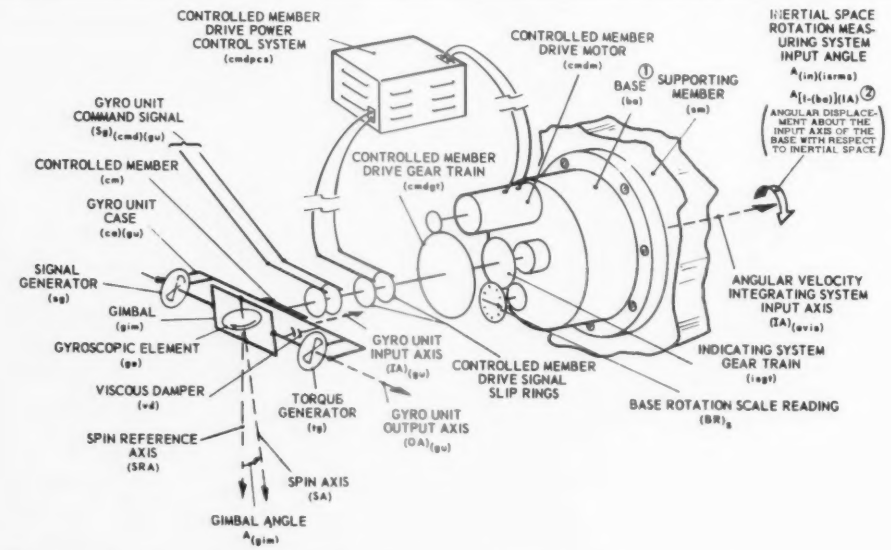
FIG. 8. Sectioned view of the M.I.T. 10[4] single-axis rate gyro unit.

wide tolerance limits. The reference position of the gyro unit case and the corresponding reference signal level are both unaffected by changes in fluid viscosity.

(3) The positions of the center of gravity of the displaced fluid and the center of gravity of the float assembly with respect to the output axis are changed by thermal gradients across the float assembly in directions at right angles to the output axis. Thermal-gradient control becomes more important as tolerance limits for drift rates due to gravity and linear accelerations are made smaller.

As a general rule, density and thermal-gradient control problems are more severe than the difficulties imposed by the adjustment of viscosity.

In Fig. 6, balance nuts are shown attached to the float assembly for adjusting the location of its center of gravity with respect to the pivot axis of the gimbal. The center of gravity is positioned as accurately as possible before a gyro unit is assembled; final adjustments are made by means of forks that can be controlled from outside the case, with the unit under actual operating conditions. The single degree of freedom float assembly is effectively a single mechanical entity that is especially designed for maximum rigidity. Therefore, in practice, its center-of-gravity positions can be adjusted and held to closer tolerances than is feasible in a two degree of freedom gyro unit, where one set of gimbal pivots is in a support system that must position


CONTROLLED MEMBER DRIVE POWER CONTROL SYSTEM (cmdpcs)
CONTROLLED MEMBER DRIVE MOTOR (cmdm)
INERTIAL SPACE ROTATION MEASURING SYSTEM INPUT ANGLE
A(in)(isrms)
A[i-(ba)](IA) ②
ANGULAR DISPLACEMENT ABOUT THE INPUT AXIS OF THE BASE WITH RESPECT TO INERTIAL SPACE
① BASE (ba)
SUPPORTING MEMBER (sm)
GYRO UNIT COMMAND SIGNAL (Sg)(cmd)(gu)
CONTROLLED MEMBER (cm)
CONTROLLED MEMBER DRIVE GEAR TRAIN (cmdgt)
GYRO UNIT CASE (ca)(gu)
SIGNAL GENERATOR (sg)
GIMBAL (gim)
GYROSCOPIC ELEMENT (ge)
VISCOUS DAMPER (vd)
SPIN REFERENCE AXIS (SRA)
GYRO UNIT INPUT AXIS (IA)(gu)
TORQUE GENERATOR (tg)
GYRO UNIT OUTPUT AXIS (OA)(gu)
SPIN AXIS (SA)
GIMBAL ANGLE A(gim)
CONTROLLED MEMBER DRIVE SIGNAL SLIP RINGS
ANGULAR VELOCITY INTEGRATING SYSTEM INPUT AXIS (IA)(avia)
INDICATING SYSTEM GEAR TRAIN (isgt)
BASE ROTATION SCALE READING (BR)s

① The base is rigidly connected to the supporting member whose rotation is to be measured.

② In the formation of a symbol that represents the angular displacement of some direction or quantity with respect to some other direction or quantity, the main symbol A is given a reference direction – compared direction subscript bracket in which the symbol for the reference quantity is followed by the compared quantity symbol, with a dash separating the two symbols. Where desirable, a further subscript symbol is added to indicate the particular axis about which the angular displacement occurs.

FIG. 9. Line-schematic diagram of a single-axis space integrator based on a single-axis integrating gyro unit and a servodriven controlled member.

the center of gravity at a point instead of bringing it into close coincidence with a line, without a close tolerance on position along the line. For precise center-of-gravity position control, it is essential that the gyro rotor bearings be preloaded to a degree that causes the rotor to have an extremely tight mechanical coupling to the float structure. It is also necessary to remove carefully any gases from the fluid space and from the fluid itself. This is done to prevent the formation of bubbles that introduce spurious torques on the float because of surface-tension effects and changes in the effective density of the fluid over local regions of the damping clearance.

An electromagnetic signal generator of the Microsyn type* is placed at one end of the float, and a Microsyn torque generator has a corresponding position at the other end of the float. Electrical power is supplied to the gyro rotor through thin flat leads that are so shaped and adjusted as to impose substantially zero torque on the float. These leads and the other electrical connections are not shown in Fig. 6.

Typical Single-Axis Gyro Units

Fig. 7 shows a sectioned view of a typical floating integrating gyro unit designed and built at the Instrumentation Laboratory, M.I.T. The features of this unit may be identified by reference to the simplified diagram of Fig. 6. The designation 10^4 means that the gyro unit has an angular momentum of 10,000 gram-cm.^{2} per sec. when the rotor is spinning at its design specification value of 8,000 r.p.m.

Fig. 8 shows a sectioned view of a rate gyro unit designed and built at the Instrumentation Laboratory. This unit is generally similar to the integrating gyro unit of Fig. 7, except for the omission of the torque generator and the replacement of one jeweled pivot by an elastic restraint bar.

Single-Axis Space Integrator with an Integrating Gyro Unit

Fig. 9 illustrates the essential features of a single-axis, servodriven angular velocity integrator similar to the one in Fig. 2. An integrating gyro unit of the type shown in Figs. 6 and 7 is used to supply the angular deviation-command signal receiving function. The action of the system shown in Fig. 9 follows the principles already discussed.

Single-Axis Gyro Unit Test Equipment

Fig. 10 shows a typical servodrive gyro unit tester based on the principle of the single-axis integrator. Provision is made for introducing known input command signals and for measuring the angular velocity of the table carrying the gyro unit as the essential output of the system. The means for measuring these quantities are also indicated.

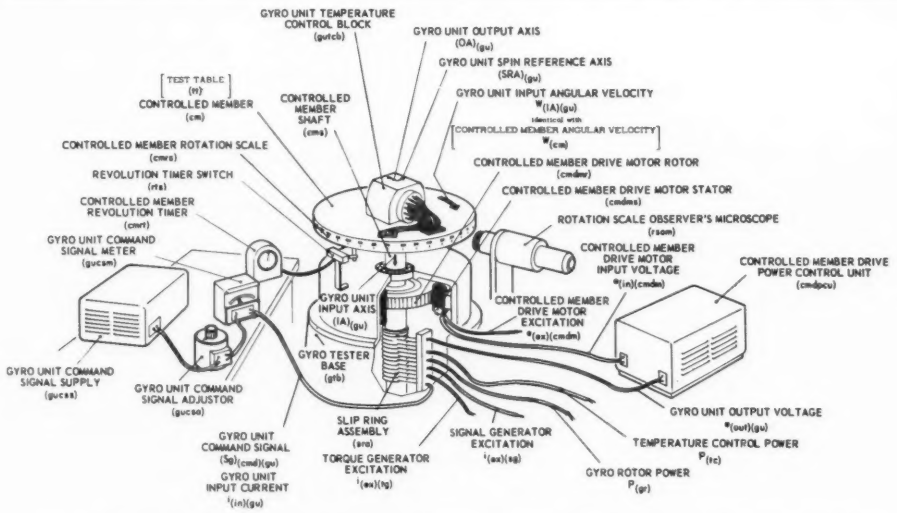
Performance Characteristics of Gyro Units

The performance characteristics that determine the effectiveness of a given gyro unit for a specific application may be considered in three categories:

(1) *Dynamic characteristics*, which describe the action of the unit during time periods when the input and output quantities† are changing.

* Microsyn signal generators are described in Fairchild Publication Fund Paper No. FF-13 and in reference 23, Vol III, Pt. 1.

† For the purposes of gyro unit performance discussions, the input may be considered to be either an angular velocity or an angle, and the output quantity may be taken as either the magnitude of the signal or the rate of change of the signal.


GYRO UNIT TEMPERATURE CONTROL BLOCK (gutcb)
GYRO UNIT OUTPUT AXIS (OA)(gu)
GYRO UNIT SPIN REFERENCE AXIS (SRA)(gu)
GYRO UNIT INPUT ANGULAR VELOCITY ω(IA)(gu)
identical with
CONTROLLED MEMBER ANGULAR VELOCITY ω(cm)
TEST TABLE (tt)
CONTROLLED MEMBER (cm)
CONTROLLED MEMBER SHAFT (cms)
CONTROLLED MEMBER ROTATION SCALE (cmrs)
REVOLUTION TIMER SWITCH (rts)
CONTROLLED MEMBER REVOLUTION TIMER (cmrt)
CONTROLLED MEMBER DRIVE MOTOR ROTOR (cmdmr)
CONTROLLED MEMBER DRIVE MOTOR STATOR (cmdms)
ROTATION SCALE OBSERVER'S MICROSCOPE (rsom)
GYRO UNIT COMMAND SIGNAL METER (gucsm)
CONTROLLED MEMBER DRIVE MOTOR INPUT VOLTAGE e(in)(cmdm)
CONTROLLED MEMBER DRIVE POWER CONTROL UNIT (cmdpcu)
GYRO UNIT INPUT AXIS (IA)(gu)
CONTROLLED MEMBER DRIVE MOTOR EXCITATION e(ex)(cmdm)
GYRO TESTER BASE (gtb)
GYRO UNIT COMMAND SIGNAL SUPPLY (gucss)
GYRO UNIT COMMAND SIGNAL ADJUSTOR (gucsa)
GYRO UNIT OUTPUT VOLTAGE e(out)(gu)
SLIP RING ASSEMBLY (sra)
GYRO UNIT COMMAND SIGNAL (Sp)(cmd)(gu)
TORQUE GENERATOR EXCITATION i(ex)(tg)
SIGNAL GENERATOR EXCITATION i(ex)(sg)
TEMPERATURE CONTROL POWER P(tc)
GYRO UNIT INPUT CURRENT i(in)(gu)
GYRO ROTOR POWER P(gr)

Note: In the actual equipment, the excitation sources, input supply, input adjustor, input meter and controlled member drive power control unit are included in a console designed for flexible and convenient use in the testing of gyroscopic equipment.

Fig. 10. Pictorial-schematic diagram for a servodrive gyro unit tester based on the single-axis space integrator.

(2) *Static characteristics*, which describe the action of the unit during time periods when the input and output quantities are both constant or varying so slowly that the behavior of the unit is effectively identical with the behavior for true static conditions.

(3) *Drift characteristics*, which describe relatively slow, spurious changes in the output signal that occur during time periods when all inputs to the unit are held constant.

Performance characteristics may be estimated from design data, but for practical purposes it is always desirable to base quantitative performance data on measurements made on complete gyro units working under carefully controlled and known operating conditions of temperature, gyro rotor power input, signal generator excitation, torque generator excitation, mechanical mounting, vibration, shock, and other environment-determining factors. To find the effects of environmental factors, it is necessary to have an accurate knowledge of the basic performance characteristics in order to differentiate clearly between inherent characteristics and changes produced by other causes. In this article, attention is confined to the measurement of performance characteristics under normal operating conditions, without consideration of environmental effects such as shock and vibration.

Dynamic Characteristics

Dynamic characteristics are determined by subjecting the gyro unit to known input changes and measuring the corresponding output signal changes. For test purposes, the transient-producing input changes may be either in the case angular velocity or in the current to the torque generator. The form of the input variation is chosen for convenience of interpreting results. Step changes, ramp changes, pulse changes, or steady-state sinusoidal changes are ordinarily used. The interpretation of results depends on the type of unit being tested.

Single-axis rate gyro units have inertial, elastic restraint and damping effects and, consequently, behave as second-order systems.* The dynamic characteristics of these systems can be described in terms of an undamped natural frequency and a damping ratio. Single-axis integrating gyro units, on the other hand, have only inertial and damping effects so that they fall into the class of first-order systems.† The dynamic characteristics of these systems may be specified in terms of a characteristic time, which is equivalent to the time constant that is associated with the behavior of a resistor-condenser series electrical circuit.

Step-function angular-velocity-input-change tests of a typical rate gyro unit with the design features represented in Fig. 8 show that the unit has an undamped natural frequency of about 21 cycles per sec. and a damping ratio of about 0.4. Step-function angular-velocity-input tests made on a typical integrating gyro unit with the design features given by Fig. 7 show that the unit has a characteristic time of about 3 millisec.

Static Characteristics of Rate Gyro Units

The static performance of rate gyro units may be determined by use of an accurate rate platform, such as an integrating-gyro-controlled, servodriven table like the one in Fig. 10. With this arrangement, the rate gyro unit to be tested is mounted rigidly to the table so that its input axis is parallel to the axis of rotation of the table. A range of angular velocity input magnitudes is produced by supplying different constant command-input currents to the integrating gyro unit that controls the table angular velocity. The corresponding output signals from the rate gyro unit under test are measured by a voltmeter.

The important static characteristic of a rate gyro unit is the *angular velocity input-voltage output sensitivity* of the unit. This quantity is defined as the ratio between the magnitude of the output voltage and the magnitude of the input angular velocity, which means that it is the slope of a curve plotted with voltage as ordinate and angular velocity as abscissa. For an ideal rate gyro unit, this curve is a straight line passing through zero, which is equivalent to stating that the unit has a perfectly linear static performance characteristic. In any actual unit, the input-output plot shows some departures from linearity. Static performance imperfections of this kind may be described in quantitative terms by taking the ratio of the slope of a line drawn from zero to any point on the input-output curve to the corresponding slope that exists over the region in which the slope is substantially constant. The ratio of these two slopes is called the *performance ratio* and is identical with the ratio of the *angular velocity-voltage sensitivity* for a particular input level to a *reference angular velocity-voltage sensitivity* chosen so that it represents the linear portion of the input-output curve.

Fig. 11 shows points for the measured performance ratio over a range of angular velocity input magnitudes for a typical rate gyro unit of the type shown in Fig. 8. The crosses represent the performance ratio (associated with the left-hand ordinate scale) as a function of the input angular velocity ratio, with 1 millirad. per sec. taken as the reference angular velocity. The points represented by "d" symbols show deviations of the performance ratio from unity as a function of the input angular velocity ratio. Numerical values for the performance ratio deviation can be obtained from the right-hand ordinate scale, which is expanded by a factor of 5 with respect to the performance-ratio scale. The points show an erratic distribution of the experimental data, with maximum limits at plus and minus $2^1/_2$ per cent deviation from unity performance ratio. This

* Derivations of rate gyro and integrating gyro performance equations are given in Fairchild Publication Fund Paper No. FF-13. The background of mathematical theory and quantitative curves in nondimensional terms for first- and second-order systems are given in reference 23, Vol II and Vol. III, Pt. 1.

† *Ibid.*

spread resulted to a considerable extent from poor performance of the indicating system used to measure the output voltage rather than from defects in the unit under test. The high angular velocity limit for operation was set at about 2,000 millirad. per sec. by the positions of mechanical stops that restrained the gimbal from tipping beyond $2^1/_2$ deg. Below an angular velocity of about 10 millirad. per sec., the erratic component of output voltage became so large in comparison with the total signal that no consistent data could be taken. This *uncertainty-determined limit* of operation was due partly to imperfections in the gyro unit and partly to various kinds of electrical interference that were present in the measuring circuits. It is probable that refinements in instrumentation and output-measurement techniques would have improved the lower limit of operation to some extent, but uncertainties associated with the rate gyro unit itself would probably have prevented satisfactory operation for input levels much less than about 5 millirad. per sec.

Static Characteristics of Integrating Gyro Units

Single-axis integrating gyro units are most effective when they are used in closed-loop systems as devices to receive angular deviations and command signals and to produce input signals for controlled member servodrive motors. In any satisfactory operating system, the servodrive motors keep deviations of the controlled member from its reference orientation so small that the gimbal angle in the gyro unit remains below the limit within which linearity of the input-output signal relationship is important. When geometrical stabilization is the desired operating characteristic—that is, when the only input to the gyro unit is angular velocity—linearity is determined by a simple summation of the gyroscopic torque and the viscous shear torque acting on the rigid gimbal structure and, for this reason, is substantially perfect for all inputs above a low angular velocity operating limit. When space integration, which provides response to orientation control signals in addition to geometrical stabilization, is an important operating requisite, changes in the relationship between the torque generator input current and the torque generator output torque will cause a deterioration of gyro unit performance at high input current levels because of magnetic saturation effects in the magnetic circuits of the torque generator.

Geometrical-stabilization and space-integration performance characteristics of integrating gyro units are

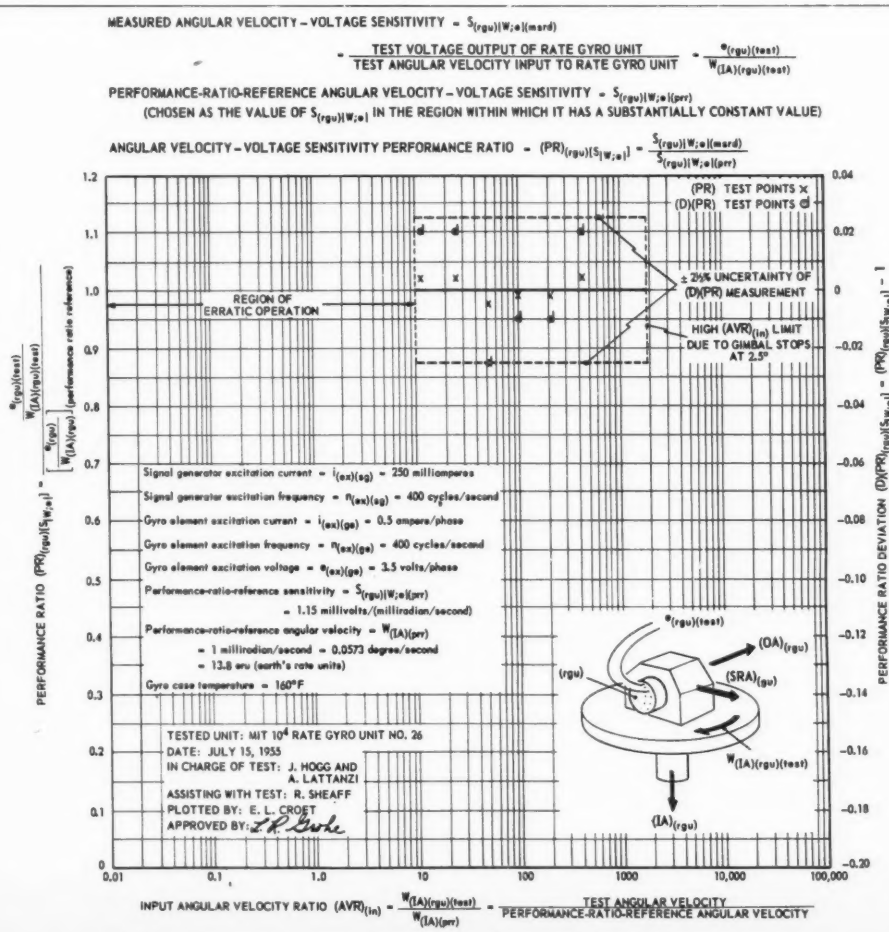

MEASURED ANGULAR VELOCITY – VOLTAGE SENSITIVITY = $S_{(rgu)(W;e)(mard)}$
= TEST VOLTAGE OUTPUT OF RATE GYRO UNIT / TEST ANGULAR VELOCITY INPUT TO RATE GYRO UNIT = $e_{(rgu)(test)} / W_{(IA)(rgu)(test)}$
PERFORMANCE-RATIO-REFERENCE ANGULAR VELOCITY – VOLTAGE SENSITIVITY = $S_{(rgu)(W;e)(prr)}$
(CHOSEN AS THE VALUE OF $S_{(rgu)(W;e)}$ IN THE REGION WITHIN WHICH IT HAS A SUBSTANTIALLY CONSTANT VALUE)
ANGULAR VELOCITY – VOLTAGE SENSITIVITY PERFORMANCE RATIO = $(PR)_{(rgu)(S_{W;e})} = S_{(rgu)(W;e)(mard)} / S_{(rgu)(W;e)(prr)}$
(PR) TEST POINTS ×
(D)(PR) TEST POINTS d
± 2½% UNCERTAINTY OF (D)(PR) MEASUREMENT
REGION OF ERRATIC OPERATION
HIGH $(AVR)_{(in)}$ LIMIT DUE TO GIMBAL STOPS AT 2.5°
PERFORMANCE RATIO $(PR)_{(rgu)(S_{W;e})} = \frac{e_{(rgu)(test)}/W_{(IA)(rgu)(test)}}{e_{(rgu)}/W_{(IA)(rgu)}}$ (performance ratio reference)
PERFORMANCE RATIO DEVIATION $(D)(PR)_{(rgu)(S_{W;e})} = (PR)_{(rgu)(S_{W;e})} - 1$
Signal generator excitation current = $i_{(ex)(sg)}$ = 250 milliamperes
Signal generator excitation frequency = $n_{(ex)(sg)}$ = 400 cycles/second
Gyro element excitation current = $i_{(ex)(ge)}$ = 0.5 ampere/phase
Gyro element excitation frequency = $n_{(ex)(ge)}$ = 400 cycles/second
Gyro element excitation voltage = $e_{(ex)(ge)}$ = 3.5 volts/phase
Performance-ratio-reference sensitivity = $S_{(rgu)(W;e)(prr)}$
= 1.15 millivolts/(millirad/second)
Performance-ratio-reference angular velocity = $W_{(IA)(prr)}$
= 1 millirad/second = 0.0573 degree/second
= 13.8 arc (earth's rate units)
Gyro case temperature = 160°F
TESTED UNIT: MIT 10^4 RATE GYRO UNIT NO. 26
DATE: JULY 15, 1955
IN CHARGE OF TEST: J. HOGG AND A. LATTANZI
ASSISTING WITH TEST: R. SHEAFF
PLOTTED BY: E. L. CROFT
APPROVED BY: C. S. Draper
$e_{(rgu)(test)}$
$(OA)_{(rgu)}$
(rgu)
$(SRA)_{(gu)}$
$W_{(IA)(rgu)(test)}$
$(IA)_{(rgu)}$
INPUT ANGULAR VELOCITY RATIO $(AVR)_{(in)} = W_{(IA)(rgu)(test)} / W_{(IA)(prr)}$ = TEST ANGULAR VELOCITY / PERFORMANCE-RATIO-REFERENCE ANGULAR VELOCITY

FIG. 11. Static performance characteristic of a typical single-axis rate gyro unit.

both affected at low angular velocity inputs by uncertainties within the units themselves. For example:

(1) Any nonviscous friction in the bearings causes erratic operation when the torques that properly control the gimbal action reach extremely low levels.

(2) Radial displacements of the float cause small but detectable changes in the output signal by introducing torque changes due to unsymmetrical variations in torque-generator and signal-generator magnetic flux gaps. Since these changes are not predictable, they must be classified as uncertainty torques.

In practical tests, various kinds of electrical interference act as uncertainties in output signals and so affect determinations of gyro unit performance.

Valid information on gyro unit performance characteristics should be based on measurements made with test equipment having such high performance that it does not itself degrade the observed results. It is particularly important that the servodrive system for the controlled member carrying the gyro unit under test be capable of operating satisfactorily over the complete angular velocity range to be explored. In practice, this means that the drive system should operate smoothly from angular velocities corresponding to small fractions of earth's rate up to angular velocities of 10 to 20 rad. per sec. In addition, the instrumentation for measuring angles and angular velocities must be capable of giving sufficiently accurate results over this angular velocity range.

Space-Integrator Operation of Integrating Gyro Units

For space-integrator operation, the important characteristic of the single-axis integrating gyro unit is the ratio of the constant angular velocity of the servo-driven controlled member carrying the gyro unit to the constant torque generator input signal that commands this angular velocity output. This ratio of output to command input, which should ideally remain constant, is determined by the balance of the torque output of the torque generator to the torque output of the gyro rotor required to hold the gimbal angle constant under static conditions. From the standpoint of externally measurable quantities, this balance depends on equating the effects of case angular velocity and torque generator current as independent inputs to the gyro unit. A measure of the effects required to produce this balance is the ratio of the *command current squared - voltage rate output sensitivity** of the gyro unit to the *angular velocity input - voltage rate output sensitivity*† of the gyro unit. This ratio is called the *current squared - angular velocity sensitivity ratio* of the integrating gyro unit. For the purpose of plotting test results to describe the essential linearity characteristic of the integrating gyro unit, the *current squared - angular velocity sensitivity ratio performance ratio* of the integrating gyro unit is defined as the ratio of the current squared - angular velocity sensitivity ratio to a reference value of this sensitivity ratio. This reference value is chosen so that the performance ratio has the value of unity over the range of angular velocities within which the performance ratio is substantially constant.

The static performance of integrating gyro units used for space-integrator operation may be obtained by means of the arrangement shown in Fig. 10 since the tester shown therein is simply a space integrator together with various measuring instruments. For test purposes, a range of constant command-input currents is applied in series to the input and excitation circuits of the torque generator of the integrating gyro unit to produce corresponding constant angular velocity magnitudes of the controlled member about the gyro unit input axis. The ratio of each resulting test angular velocity to the square of the test input current that produced it is identical with the current squared - angular velocity sensitivity ratio for the particular value of input current applied. It is important to note that with a fixed excitation to the torque generator, such as would be used in any normal linear application of the integrating gyro unit, practical limitations of the torque generator cause the linear operating range to be less than when a common input current is applied in series to the input and excitation circuits. The reduction in operating range is at least two decades, and in most cases more. The series test arrangement has the advantage that it allows the performance ratio test to show the full angular velocity operating range inherent in the integrating gyro unit, exclusive of certain torque generator limitations.

Fig. 12 shows a performance ratio plot for a typical single-axis integrating gyro unit tested for the space-integrator mode of operation. The independent variable plotted on the logarithmic abscissa scale is the command input angular velocity ratio,‡ with 1 millirad. per sec. as the reference angular velocity. The ordinate scale on the left-hand side of Fig. 12 is for the current squared - angular velocity sensitivity ratio performance ratio and has both zero and unity on the scale. The right-hand ordinate scale is for the performance ratio deviation, which is the performance ratio minus unity. This scale is expanded by a factor of 5 with respect to the left-hand ordinate scale.

The solid-line plot of Fig. 12 shows that the performance ratio of the tested gyro unit remained within 1 per cent of unity between 0.1 and 4,000 millirad. per sec.

* The command current squared - voltage rate output sensitivity of the integrating gyro unit is defined as the ratio

$$\left(\frac{\text{(rate of change of output signal voltage under static conditions)}}{\text{(product of torque generator input current and torque generator excitation current under static conditions)}}\right)$$

† The angular velocity input - voltage rate output sensitivity of the integrating gyro unit is defined as the ratio

$$\frac{\text{(rate of change of output signal voltage under static conditions)}}{\text{(angular velocity input to gyro unit under static conditions)}}$$

‡ The command input angular velocity is the output angular velocity that the space integrator controlled member would have if the space integrator were ideal—that is, if the gyro unit *current squared - angular velocity sensitivity ratio* were constant at the performance-ratio-reference value.

At the high angular velocity limit of the unity performance ratio region, the performance ratio curve falls away from unity (and the deviation curve goes into negative values) because of magnetic saturation effects in the torque generator. At the low angular velocity limit, the experimental data points lie erratically distributed between two curved boundaries. This shows that, for low angular velocities, uncertainty effects make it impossible to rely on the angular velocity output of the space integrator to tolerance limits closer than those indicated by the plot. It is probable that the uncertainty region of Fig. 12 could be reduced by refinements in manufacture, adjustment, and operating-condition control of the gyro unit. In any event, it is to be expected that uncertainties will always exist for sufficiently small angular velocity ratios and that, except for numbers on the abscissa scale, the corresponding performance ratio plot will be generally similar to that of Fig. 12.

The deviation curve of Fig. 12 shows that, if tolerance limits on linearity of performance are set at a $2^1/_2$ per cent deviation from ideal operation, the integrating gyro unit tested is satisfactory between a low angular velocity limit of 0.04 millirad. per sec. to an upper limit of about 7,000 millirad. per sec. This gives an operating range of 1 to 175,000 for the stated tolerance limits. The corresponding operating range for the rate gyro unit whose static performance is described in Fig. 11 is 10 to 2,000 millirad. per sec.—that is, a range of 1 to 200. The much greater region of linear operation for the integrating gyro unit when used for controlling a single-axis space integrator, in comparison with the rate gyro unit when used for making angular velocity measurements, is due partly to the inherent superiority of the integrating gyro unit design and partly to the greater accuracy of time and angle measurements, compared with alternating-current voltmeter readings, for obtaining output determinations.

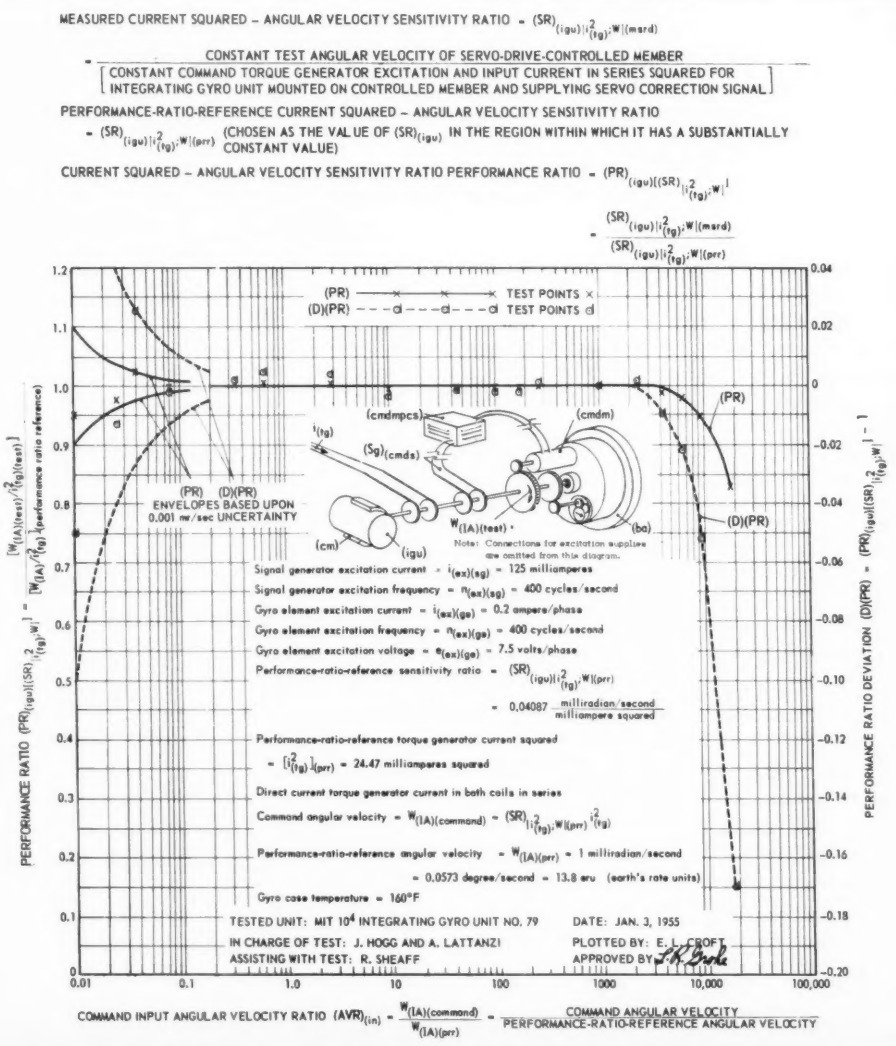

MEASURED CURRENT SQUARED – ANGULAR VELOCITY SENSITIVITY RATIO = $(SR)_{(igu)}i^2_{(tg)};W|(msrd)$
= CONSTANT TEST ANGULAR VELOCITY OF SERVO-DRIVE-CONTROLLED MEMBER / [CONSTANT COMMAND TORQUE GENERATOR EXCITATION AND INPUT CURRENT IN SERIES SQUARED FOR INTEGRATING GYRO UNIT MOUNTED ON CONTROLLED MEMBER AND SUPPLYING SERVO CORRECTION SIGNAL]
PERFORMANCE-RATIO-REFERENCE CURRENT SQUARED – ANGULAR VELOCITY SENSITIVITY RATIO
= $(SR)_{(igu)}i^2_{(tg)};W|(prr)$ (CHOSEN AS THE VALUE OF $(SR)_{(igu)}$ IN THE REGION WITHIN WHICH IT HAS A SUBSTANTIALLY CONSTANT VALUE)
CURRENT SQUARED – ANGULAR VELOCITY SENSITIVITY RATIO PERFORMANCE RATIO = $(PR)_{(igu)|(SR)_{i^2_{(tg)};W}|}$
= $(SR)_{(igu)}i^2_{(tg)};W|(msrd) / (SR)_{(igu)}i^2_{(tg)};W|(prr)$
(PR) TEST POINTS ×
(D)(PR) TEST POINTS d
(PR) (D)(PR) ENVELOPES BASED UPON 0.001 mr/sec UNCERTAINTY
(cmdmpcs)
(cmdm)
$i_{(tg)}$
$(Sg)_{(cmds)}$
$W_{(IA)(test)}$
(cm)
(igu)
(ba)
Note: Connections for excitation supplies are omitted from this diagram.
Signal generator excitation current = $i_{(ex)(sg)}$ = 125 milliamperes
Signal generator excitation frequency = $n_{(ex)(sg)}$ = 400 cycles/second
Gyro element excitation current = $i_{(ex)(ge)}$ = 0.2 ampere/phase
Gyro element excitation frequency = $n_{(ex)(ge)}$ = 400 cycles/second
Gyro element excitation voltage = $e_{(ex)(ge)}$ = 7.5 volts/phase
Performance-ratio-reference sensitivity ratio = $(SR)_{(igu)}i^2_{(tg)};W|(prr)$
= 0.04087 milliradian/second / milliampere squared
Performance-ratio-reference torque generator current squared
= $[i^2_{(tg)}]_{(prr)}$ = 24.47 milliamperes squared
Direct current torque generator current in both coils in series
Command angular velocity = $W_{(IA)(command)} = (SR)_{i^2_{(tg)};W|(prr)} i^2_{(tg)}$
Performance-ratio-reference angular velocity = $W_{(IA)(prr)}$ = 1 milliradian/second
= 0.0573 degree/second = 13.8 aru (earth's rate units)
Gyro case temperature = 160°F
TESTED UNIT: MIT 10^4 INTEGRATING GYRO UNIT NO. 79
DATE: JAN. 3, 1955
IN CHARGE OF TEST: J. HOGG AND A. LATTANZI
PLOTTED BY: E. L. CROFT
ASSISTING WITH TEST: R. SHEAFF
APPROVED BY: C. R. Burke
PERFORMANCE RATIO $(PR)_{(igu)|(SR)_{i^2_{(tg)};W}|} = [W_{(IA)(test)}/i^2_{(tg)}(test)] / [W_{(IA)}/i^2_{(tg)}$ (performance ratio reference)]
PERFORMANCE RATIO DEVIATION $(D)(PR) = [(PR)_{(igu)|(SR)_{i^2_{(tg)};W}|}] - 1$
COMMAND INPUT ANGULAR VELOCITY RATIO $(AVR)_{(in)} = W_{(IA)(command)} / W_{(IA)(prr)}$ = COMMAND ANGULAR VELOCITY / PERFORMANCE-RATIO-REFERENCE ANGULAR VELOCITY

FIG. 12. Static performance characteristic of a typical single-axis integrating gyro unit tested for the space-integrator mode of operation.

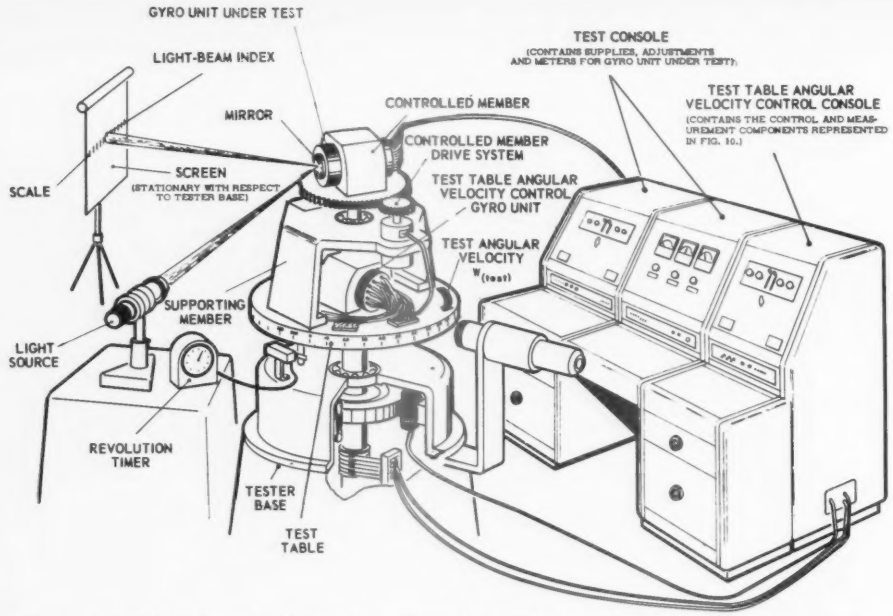


FIG. 13. Pictorial-schematic diagram of a tester for single-axis geometrical stabilization systems.

In making observations of rate gyro unit performance, the angular velocity input levels were known to the same degree of accuracy as the angular velocity output levels of the space integrator, inasmuch as the space integrator was commanding the velocity level of the test table on which the rate gyro unit was mounted. However, since the rate gyro unit output data were taken with an ordinary vacuum-tube voltmeter, without extensive circuit refinements, electrical interference effects including "noise," "higher harmonics," and "quadrature component" influenced the results, particularly at low angular velocities. Considerable effort would have been required to reduce greatly the interference effects in the rate gyro unit tests. This effort was not made because the operating conditions that existed were generally similar to those that may be expected in practical applications of the units.

The integrating gyro unit tests represented the operating conditions to be expected in practice to about the same degree that the rate gyro unit tests did. The use of a well-regulated supply of direct current (available under usual operating conditions) as the source of command signals for the integrating gyro unit greatly simplified the problem of accurately measuring the constant input levels used in the tests.

Even with output and input measurement difficulties accounted for, the range of satisfactory operation of the integrating gyro unit is much wider than the corresponding range for the rate gyro unit. This difference in the size of the operating region is due to many effects that act in the rate gyro unit but not in the integrating gyro unit. These include hysteresis in elastic restraint springs, misalignment in the zero settings of the elastic restraint and the signal generator, and mechanical vibrations. However, the basic limitation of the rate gyro unit is introduced by the fact that increasing the angular velocity input must cause the gimbal deflection with respect to the case to become greater up to some definite limit that is set by the maximum specified tolerance of the unit for angular velocities about the spin reference axis. This problem of coupling due to increasing gimbal angle does not exist for the integrating gyro unit when it is associated with a properly designed servosystem having sufficient gain and integration in the amplifier unit. The use of high gain means that the integrating gyro unit produces all the required voltage input to the servo for extremely small gimbal angles.

The integrating gyro unit is not subject to hysteresis, nonlinearity, and misalignment difficulties associated with elastic restraint springs because its design does not include springs of this kind. Another factor in favor of the integrating gyro unit is the presence of heavy viscous damping which tends to reduce interference effects due to mechanical vibrations excited by the spinning rotor of the gyro unit.

GEOMETRICAL-STABILIZATION OPERATION OF INTEGRATING GYRO UNITS

Geometrical-stabilization operation of integrating gyro units is the special case of space-integrator operation that exists when the command input signal is made equal to zero.* To take data on the effectiveness of any integrating gyro unit - servodrive system combination

* As a general rule, spurious torques due to mechanical unbalances, signal generator reaction, torque generator reaction, gyro power lead-in wires, and other actions cause drift angular velocities to exist in a gyro-controlled, servodriven controlled member. It is possible to compensate for the resultant of these effects by applying a proper correction signal to the gyro unit via the torque generator. This correction signal is not regarded as an input component to the gyro unit.

for geometrical stabilization, a test arrangement with the features shown in Fig. 13 may be used. The geometrical stabilization system is mounted on a space-integrator type of test table and is fitted with means for measuring angular displacements of the stabilized controlled member with respect to the base that carries the test table. When the test table is given a known angular velocity with respect to inertial space by supplying a controlled command signal to the gyro unit fixed to the table, the difference between the controlled member angular velocity and the test-table angular velocity may be measured by means of a scale that is fixed with respect to the base of the test equipment. When observations of this kind are made for a series of input angular velocities, it is possible to make a performance ratio plot similar to that given in Fig. 12 for space-integrator operation. Fig. 14 gives a plot of this kind for a typical integrating gyro unit. In this plot, the performance ratio is based on the ratio of the angular velocity of the stabilized controlled member with respect to the table that carries the geometrical stabilization system to the angular velocity of the table with respect to inertial space. This means that earth-rotation effects must be either compensated by proper signals to the gyro unit under test or taken into account by computed corrections.

The performance ratio and performance ratio deviation plots of Fig. 14 are generally similar to the plots of Fig. 12 for space-integrator operation. The angular velocity limit for a tolerance limit of 1 per cent uncertainty occurs at 0.1 millirad. per sec. Although the extreme right-hand experimental point is located at 400 millirad. per sec., no deterioration in performance is shown for the high angular velocity ratio region. From the standpoint of gyro unit performance, the assumption of no high angular velocity limit is justified by the fact that effects due to imperfect operation of the torque generator, the gyro rotor, the viscous shear damper, or the rigid-structure coupling between these operating components are nonexistent in this case. In any practical stabilization system, the high angular velocity limit of performance will be set by the ability of the

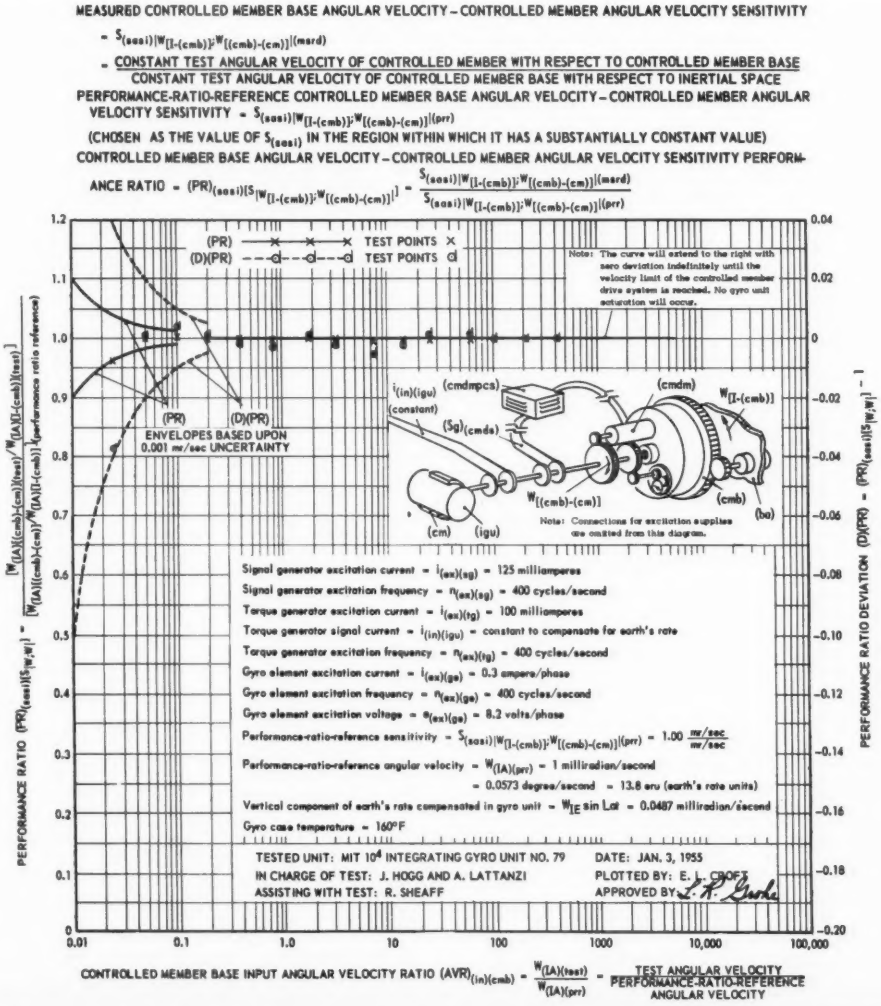

MEASURED CONTROLLED MEMBER BASE ANGULAR VELOCITY – CONTROLLED MEMBER ANGULAR VELOCITY SENSITIVITY
CONSTANT TEST ANGULAR VELOCITY OF CONTROLLED MEMBER WITH RESPECT TO CONTROLLED MEMBER BASE
CONSTANT TEST ANGULAR VELOCITY OF CONTROLLED MEMBER BASE WITH RESPECT TO INERTIAL SPACE
PERFORMANCE-RATIO-REFERENCE CONTROLLED MEMBER BASE ANGULAR VELOCITY – CONTROLLED MEMBER ANGULAR VELOCITY SENSITIVITY
(CHOSEN AS THE VALUE OF IN THE REGION WITHIN WHICH IT HAS A SUBSTANTIALLY CONSTANT VALUE)
CONTROLLED MEMBER BASE ANGULAR VELOCITY – CONTROLLED MEMBER ANGULAR VELOCITY SENSITIVITY PERFORMANCE RATIO
(PR) TEST POINTS
(D)(PR) TEST POINTS
Note: The curve will extend to the right with zero deviation indefinitely until the velocity limit of the controlled member drive system is reached. No gyro unit saturation will occur.
ENVELOPES BASED UPON 0.001 mr/sec UNCERTAINTY
(cmdmpcs)
(constant)
(cmdm)
(cmdo)
(cmb)
(cm)
(igu)
(ba)
Note: Connections for excitation supplies are omitted from this diagram.
Signal generator excitation current = 125 milliamperes
Signal generator excitation frequency = 400 cycles/second
Torque generator excitation current = 100 milliamperes
Torque generator signal current = constant to compensate for earth's rate
Torque generator excitation frequency = 400 cycles/second
Gyro element excitation current = 0.3 ampere/phase
Gyro element excitation frequency = 400 cycles/second
Gyro element excitation voltage = 8.2 volts/phase
Performance-ratio-reference sensitivity = 1.00 mr/sec / mr/sec
Performance-ratio-reference angular velocity = 1 milliradian/second
= 0.0573 degree/second = 13.8 aru (earth's rate units)
Vertical component of earth's rate compensated in gyro unit = 0.0487 milliradian/second
Gyro case temperature = 160°F
TESTED UNIT: MIT 10⁴ INTEGRATING GYRO UNIT NO. 79
IN CHARGE OF TEST: J. HOGG AND A. LATTANZI
ASSISTING WITH TEST: R. SHEAFF
DATE: JAN. 3, 1955
PLOTTED BY: E. L. CROFT
APPROVED BY: C. S. Draper
PERFORMANCE RATIO
PERFORMANCE RATIO DEVIATION (D)(PR)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
-0.20
0.01
0.1
1.0
10
100
1000
10,000
100,000
CONTROLLED MEMBER BASE INPUT ANGULAR VELOCITY RATIO
TEST ANGULAR VELOCITY / PERFORMANCE-RATIO-REFERENCE ANGULAR VELOCITY

FIG. 14. Static performance characteristic of a typical single-axis integrating gyro unit tested for the geometrical-stabilization mode of operation.

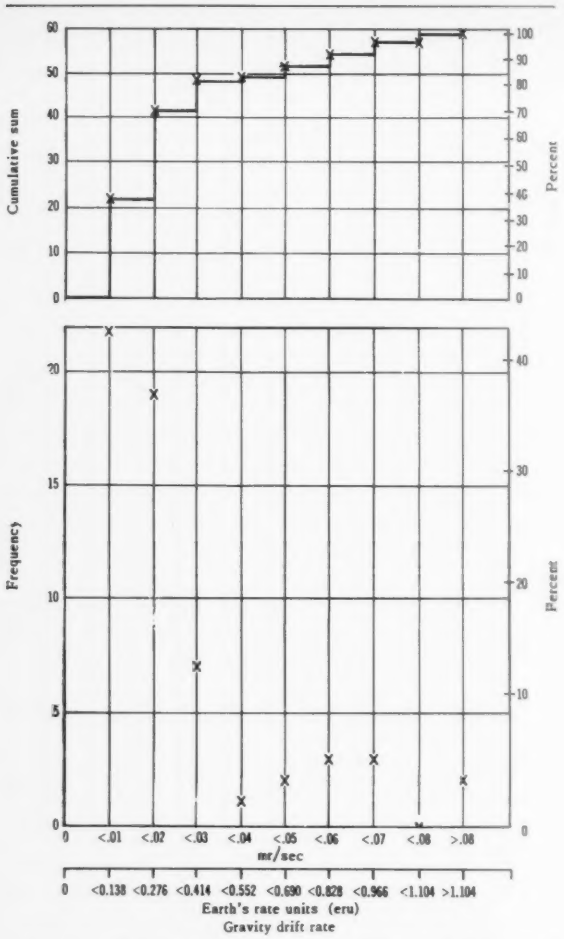


FIG. 15. Plot of statistical frequency and cumulative sum of 59 gravity drift rate measurements made on 30 M.I.T. 10^4 integrating gyro units.

servodrive to produce high angular velocities and high angular accelerations.

FEEDBACK GYRO RATE INDICATING SYSTEM

Integrating gyro units may be used as the essential elements of angular velocity measuring systems by feeding the output signal back to the torque generator through an amplifier so that the gimbal angle is held at null by the torque generator output. With this arrangement, the feedback current to the torque generator may be taken as a measure of the angular velocity input to the gyro unit.

The feedback gyro rate indicating system makes it possible to take advantage of the good low-angular-velocity-region performance that is characteristic of the integrating gyro unit. When alternating current is used as the feedback-generated input for the gyro unit and angular velocity readings depend on indications of the magnitude of this current, the a.c. measurement difficulties* already mentioned in the discussion of rate gyro unit performance are still present in the feedback gyro rate indicating system. However, this use of the integrating gyro unit will result generally in better angular velocity measurement signals since the signal fed back to the torque generator is at a high electrical level, is a measure of the torque about the gyro unit output axis, and is not so critically influenced by the angular resolution of the signal generator.

In the high angular velocity region, if electrical feedback and output-indication problems are assumed to be satisfactorily solved, the performance of the feedback gyro rate measurement system should be limited only by the gyro unit itself. In practice, it may not be necessary to design for rate measurements up to the gyro-unit determined maximum, in which instance a simplified electrical feedback system may be accepted as the limiting component.

Performance ratio plots for feedback gyro rate indicating systems are generally similar to the rate gyro unit plots of Fig. 11, except that the high angular velocity limit is set by a saturation-type drooping of the curve rather than the sudden break due to motion-limiting stops on the gimbal.

RATE GYRO DRIFT

Drift-rate measurements for a rate gyro unit are made by observing the output signal when the input angular velocity is zero. This spurious component of the output is principally due to misalignment that causes the minimum output from the signal generator to occur at a gimbal angle that differs from the zero torque angle for the elastic restraint spring, including adjustment tolerances and mechanical hysteresis effects.

Observations made on a rate gyro unit with the features shown in Fig. 8 show a drift component in the output signal equivalent to an input angular velocity of about 1.4 millirad. per sec.

INTEGRATING GYRO DRIFT

Drift rate for an integrating gyro unit is associated with the input angular velocity necessary to hold the output signal from the signal generator at null. Drift rate has systematic (error) components and erratic (uncertainty) components. The systematic components are due to the action of gravity and linear accelerations on mechanical unbalance in the gimbal and to spurious effects associated with the gyro drive current lead-ins, the signal generator, the torque generator, and elastic deformations of the gimbal structure. Compensation may be supplied to the torque generator to balance out systematic torque components due to the last four causes, but the mechanical unbalance torques depend on the orientation of the resultant force direction with respect to the gyro unit. With these orientation effects taken into account, systematic drift-producing torque components may be compensated so that they do not affect gyro unit performance. On the other hand, there are residual uncertainty components that cannot be eliminated; these determine the ulti-

* These a.c. measurement difficulties may be no worse than the undesirable effects introduced by magnetic hysteresis when using direct current with no hysteresis erasing system.

mate performance of the gyro unit. Limits of variation of the residual drift rates of a gyro unit are suitable measures of drift rate uncertainties.

Fig. 15 summarizes the results from gravity drift rate measurements made on a number of single-axis integrating gyro units. Each gravity drift rate measurement was determined by two earth-rate-corrected measurements of total drift rate: (1) with the output axis vertical and (2) with the input axis vertical. The first measurement contains no gravity-drift-rate component since the effect of gravity on any mass unbalance cannot produce a torque about the output axis when the output axis is vertical. Drift rate in this position is due solely to the spurious effects noted in the preceding paragraph. The second measurement contains drift rates due to both mass unbalance and the spurious effects. The first measurement was subtracted from the second to yield the gravity-sensitive component of the total drift rate with the gyro input axis vertical. The total number of gravity-drift-rate measurements thus obtained were tabulated and then grouped to give the points on Fig. 15. This figure shows that the gravity drift rates in 95 per cent of the measurements were no greater than earth's rate and in 70 per cent of the measurements were no greater than about one-quarter of earth's rate. Typical measurements of the gravity-sensitive component of total drift rate with the gyro spin reference axis vertical follow the same pattern shown in Fig. 15.

Conclusions

The floated integrating gyro unit is capable of a high level of performance in its application to geometrical stabilization, space integration, and rate measurement problems. It possesses a number of advantages over the single-axis spring-restrained rate gyro unit. The most important advantage results from the conflicting requirements on the rate gyro unit which come about in determining the amount of gimbal angle deflection for a given angular velocity input. If this angle is designed to be small, the resolution with which the angular velocity indications may be read is limited because of the small range over which the signal generator rotor turns. If, on the other hand, the angle is allowed to be large, two difficulties may appear:

(1) Assuming that the angular momentum of the gyro rotor is to be kept constant, an increase in gimbal angle for a given input angular velocity can be achieved only by a decrease in gimbal elastic restraint, which is accompanied by a corresponding undesirable reduction in speed of response.

(2) Large gimbal angles lead to problems of interaxis coupling in that angular velocities about the spin reference axis can cause torques on the gimbal and false angular velocity indications.

It is often impossible to achieve a compromise in a rate gyro unit that will meet all requirements of a given system application. In situations of this kind, an integrating gyro unit will generally give satisfactory results when it is used as a space integrator or in a feedback arrangement. A system of the feedback type has a good resolution of indicated rate since it uses the torque generator current, not gimbal angle, as its indication. It can be operated very close to zero gimbal angle, depending upon the design effort put into the controlled member drive system, and, because of this, the unit is not subject to an appreciable error from geometrical coupling effects.

From the standpoint of dynamic performance, the integrating gyro unit with a time constant of a few milliseconds has a much faster response than the other components that make up many of the systems in which it is applied so that its effects on the dynamic performance of these systems are negligibly small.

It is important to note that the controlled member drive cannot be charged to the integrating gyro unit as additional equipment. In almost every application, this drive exists as a positional or velocity servo that orients the gimbal, platform, or structure of the supporting member. The application of the integrating gyro unit merely puts this unit into the existing servo-loop.

Every problem associated with geometrical stabilization with respect to inertial space and angular velocity measurement that has so far come to the attention of the authors can be successfully met by the use of the single-axis integrating gyro unit.

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The problems of weapon systems planning viewed from the business and management, rather than technical, standpoint.

The Planning of Systems and Products for the Military Services

L. L. Stahl*
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Introduction

For the past several years, it has been quite fashionable to discourse on technical considerations which relate to the planning of weapon systems or products for the military services. Feeling that a sufficient amount has been written about the engineering and technical aspects, this author will treat the problems posed to that level of management where all of the business and engineering problems must be viewed and weighed together. More specifically, the discussion that follows deals with matters which can never be expressed in closed form and which quite often are opinions formed after an analysis of as many pertinent facts as can be gathered.

For discussion purposes, the planning will be divided into two phases—market intelligence and analysis of the planning process itself. The areas which will be discussed in market intelligence are classic—location of the market, need for the system or product, size of the market, customer vagaries, value of the product, and position and products of competitors. In the analysis of the planning, we will examine definition of the problem, the product effectiveness measure, the product to solve the problem, and the company's position with respect to the system or product and its timing.

Market Intelligence

Market intelligence begins with the determination of the location of the market—location with respect to a Service or Services which need the product. Having now admitted of a need, in all fairness it should be determined whether or not the system or product will pose any inter-Service or intra-Service problems. For example, it is easy to visualize guided-missile systems which lie in "gray" areas of Service responsibility and could possibly go to one or more Services. Now if the Services are unable to agree as to which Service will be the development proponent, the problem may be referred to the Joint Chiefs of Staff or the Secretary of Defense for decision. Naturally, this is time consuming and can result in delay of initiation of the particular program. Closely allied to this facet of the problem is the relationship of the proposed product to current and future Service roles and missions. An excellent criterion in pinpointing the location of the market is developed by extrapolation into future roles and missions and thus determining where the system properly belongs. The last, and easiest, item is to ascertain the identity of the military planners and procurement people who will be identified with the product. The planners especially will have given much serious thought to problems relating to employment of the new product and can be of invaluable assistance as a new area is explored. To sum up, simply because a Service, or Service component, is enthusiastic about a system, this does not fix the market location. The propriety of the location must be examined, or else one will ultimately find himself dealing with the wrong customer.

The true need of the military services is most important from a business standpoint. This is most vividly illustrated by the fact that, if the product or system is not predicated on a valid, continuing need, sooner or later this will be recognized and will be reflected in the sudden diminution and subsequent termination of the program. From a business standpoint, this could be well-nigh catastrophic—catastrophic because the item is now relegated to limbo, and thus the engineering talent expended has been wasted. It takes several years to nurse a system to the production stage; therefore, when a system ceases to be, the factory will in all probability be empty for the development lead time of the next system. If a requirement for a product is established, it is also well to ascertain whether it was the result of a command decision, coordinated staff opinion, or some political, military maneuver. A command decision may indicate either strong personal conviction or extreme indecision at lower levels. It can be reoriented as easily as it was made and

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is therefore a perilous long-term planning foundation. Coordinated staff opinion represents a balanced, logical position which has the best chance of survival through thick and thin. A political maneuver is the result of current climate and, with a climate change, may no longer be in favor. Indeed, it may well be a "dead cat" around someone's neck. If the requirement is yet to be established, it is well to know by what staff processes it will come into life so that the staff people can have made available to them the experience and knowledge of various defense businesses. This experience and knowledge can most certainly aid and assist the military as they promulgate and delineate the requirement. Further, the need has to be pinpointed to a present or future need, and then the expected lead time added to the beginning point indicates when the product will be a fact of business life. Once again, the criticalness of the validity of the need cannot be overemphasized, and bear in mind that it is not a valid need unless the system makes military—tactical or strategic—sense. It would be stupid indeed to develop a better fungus-proofing for bows and arrows. In short, the product must fit into the tactics and strategy planned for future warfare. Coupled with this tactical-strategic consideration, one should ask, "Is it a weapon for offense or defense, and precisely where will it fit into the future pattern?" A little later, we shall see how these questions and their answers relate to several other pertinent problems.

One of the more common management queries involves the anticipated size of the market for a proposed system or product. Fortunately, there are several engineering and military considerations which can enable one to make a good first-order approximation of this size. If a system provides a defensive capability, it is reasonable to assume that the D-Day requirements will be purchased *in toto* before the anticipated D-Day. Stated another way, whatever defensive systems are required to withstand the first onslaught of the enemy simply have to be purchased and in operational use. On the other hand, if the product is for offense, sufficient numbers must exist to support planned actions in all parts of the world. Another aid in size determination is found in an analysis of whether the system will be employed in the continental United States or in a theater of operations. If it is suited only for use in the zone of the interior, its limit can be narrowed down; but, if it will be employed in active theaters, the size-determination problem is compounded. A good illustration of this point is found in antiaircraft weapon systems. A complex, immobile system would be used only for protection of worth-while targets in the United States. A system with limited mobility could be used in the continental limits and for defense of static, overseas installations. A truly mobile system could be employed anywhere.

Another significant clue to the size of the market is contained in the anticipated military level of system employment. By level, reference is made to whether units equipped with this product or system would be found as organic elements in a battalion, a regiment, a division, a corps, an army, or an army group. It is perfectly obvious that a product which can be used by small tactical units will be procured in much greater numbers than some extremely complex system which can be efficiently employed and controlled only at a very high command echelon. The product lead time can also exert considerable influence on the quantities that will be procured. For instance, there is a natural reluctance to procure devices which take a long time from order given to order filled, because this length makes the system vulnerable to being overtaken by technical progress and thus experience a change in planning and procurement attitudes—usually evidenced by lesser quantities. Another measure of size can be found in examining anticipated peacetime purchases, mobilization reserve purchases, and wartime purchases. The quantity of these purchases is affected by the product lead-time because either the D-Day plus lead-time requirements are on hand or a calculated risk is accepted. In this respect, more of a risk would be accepted in items for offense than those for defense because, if war comes, without the defense you are finished; but a shortage in offense equipments merely delays assumption of the offense Not to be overlooked, too, are critical components which are in or related to the proposed product and over which there is Government control. The boundaries of this procurement may then be limited by other than military and economic considerations. As an example, it is difficult to visualize procurement of quantities of atom-bomb delivery vehicles which is not related to numbers of atom bombs available. Finally, the Services' budgets should be scrutinized from a historical and forecast viewpoint to ascertain whether the now estimated market can be supported by the necessary funds.

Let us turn our attention now to Service attitudes and preferences. We must consider the business' reputation with respect to its products, services offered, and development capabilities. If a poor reputation exists in any of these areas, the reasons therefore must be known and analyzed so they may be considered and acted upon during the planning process. In the matter of service attitudes, consideration should be given to the impact of the product. If it is going to mean the end of a branch of a Service, it is reasonable to expect bitter opposition to the product in one form or another. A final matter is to determine military preferences which will support the adoption, and thus sale, of the system.

Price is a term which is often used but which must be discarded in the approach to items for the military services. The real way to determine what has been called price is to ask, "What is this product or system value?" This value is a little hard to nail down, but it can be measured in terms of personnel economies which can be afforded, dollar economies which will result, and the accrual of military advantages. Strategic and tactical advantages most assuredly affect the value. The level of support afforded the military establishment cannot be based wholly on "dollar economy" but

must give proper weight to military considerations. To illustrate this point, a life insurance policy is viewed not as a problem in economy but solely from the viewpoint of the protection and benefit it promises to afford. So it is, and so it should be, for military procurement. Dollars are not everything, but significant strategic and tactical advantages are. A convenient mathematical tool to express value is found in a so-called *effectiveness quotient*. A simple illustration of this point is the value of an antiaircraft defense system. For instance, compute the cost per kill of an existing system, and then compute the cost per kill of a replacement system. This cost is comprised of such items as original equipment price properly amortized, maintenance costs, personnel salaries, training expenses and expenditures, attrition costs, and modification expenses. The kill is one aircraft attacked in a selected fashion and destroyed to an agreed degree. It should certainly cost less (men and money) with an improved system than with an existing system.

Lastly, let us turn our attention to that "unsavory" character, the competitor. It is well known that you should cast a wary eye about and determine who else is in the particular type of business being scrutinized. What is their market position, their reputation and capabilities? If possible, and this is difficult because of security and proprietary considerations, are they proposing a competitive product to the one which you are now considering? If they are, a realistic vis-à-vis comparison must be effected. There is no more fatal trap than to be deluded by poor market intelligence and knowledge.

An Analysis of the Planning Process

We have now accumulated the necessary amount of market intelligence and have attempted to measure what it says—from the standpoints of both management and business. The next step is to formulate a business plan of action based on the best information obtainable. An analysis of the steps in such planning follows.

To begin, we note that scrutiny of the problem logically divides into:

(1) The first and most important aspect is to delineate the problem carefully and precisely. Definition of the problem with the utmost clarity and precision serves as an invaluable aid in clearing away cobwebs.

(2) Why does the problem exist? What facets of national policy, military strategy, military tactics, technology, and economics relate to and give rise to the problem? Unfortunately, here assumptions must sometimes be made. The validity of the assumptions cannot be overemphasized. If assumptions need to be made, be sure to get a close check of opinion as to their validity. This is the only guard against being so bemused by the problem that you cannot see the forest for the trees (or the guided missile for its wings).

(3) A further assistance in pinpointing the problem is to ascertain where the mission will be performed or the need met. This includes geographical location, friendly and enemy military environment, and the technological environment. Geographical location needs no amplification. The environments do call for elaboration. Everyone says weapons need to be simple, rugged, and reliable, and this can never be overemphasized. Technological environment bears on the problem, too. The most obvious areas are in the problems now being posed by the greatly expanded dependence upon electromagnetic radiation. Inviolable physical laws which govern radiation phenomena must be considered from the concept's initiation.

(4) When is this product going to be required in time? Can there be found an absolute time, or is the timing related to another situation? To take an example, when intelligence estimates indicate the emergence of enemy pogosticks, the development and production timing of antipogostick weapon systems can be intelligently set forth. There are numerous historical examples of this principle, but their discussion is precluded by security requirements.

In market intelligence, we dwelt on the effectiveness quotient as a method of determining value. This effectiveness quotient is the ratio of the output to the input. The output could be tanks destroyed, aircraft crippled, soldiers irradiated, or communications links jammed; the input will be men, their equipment, and the necessary moneys to bring together and support the men and the equipment at the needed time.

The first time attention is brought to bear on a system or product, it is important not to become lost in a maze of detail. As we generalize characteristics, only fundamentals can be considered. Precise calculation is not required because significant advantages are being investigated. A good way to start is to set down the characteristics of the perfect product to satisfy the problem boundary conditions. Having put down on paper the ultimate—or perfect—answer, we then find an answer which is attainable. Why the attainable differs from the ultimate is significant. It may well point toward another product which will overtake the near-term answer or indicate where future effort is needed to effect a significant breakthrough. Also we usually find ourselves in a "gray" area because of competitive solutions. Needless to say, you cannot do everything; so the most attractive needs to be selected. Now, let us project this solution into future strategy and tactics. How well does it fit? Has the engineer done something which has produced a militarily unacceptable system or product? Coupled with this is obsolescence. Can obsolescence be caused by friendly or enemy technological progress, possible military considerations, or high-level political decision? A striking illustration of this last point is found in the atom bomb. If the nations of the world ban the use of atomic weapons, the position of systems which depend on the destructive atom is perilous indeed. Our market intelligence has given us a feeling for the quantities to be involved. These quantities cannot be overlooked as we characterize the product. It should be relatively easy to have small groups of skilled technicians operate one or two intricate systems, but it would not be feasible to do this for significant quantities. As we conclude our look

at this proposed product, we must in summary evaluate and recommend. Remember that the value is expressed in terms of economies—in men and money—and tactical and strategic advantages. A tentative price needs to be set, and then a feeling for the Services' desire to purchase and ability to purchase must be developed.

The next phase is to examine the company with respect to the product or system:

(1) Where are the personnel—engineering and manufacturing—coming from to do the work? Are the necessary talents and skills available in the work force of the company? The proper work force must be available and factored in or else the plan is meaningless.

(2) Facilities are equally important. Where will the development take place; after development is completed, what production capability could be set aside? The use of Government-owned facilities is inviting but is surrounded by many thought-provoking pros and cons. Company-owned facilities obviously require capital expenditures, but they afford easier control of the business' destinies.

(3) Related to personnel are the military requirements for maintenance of the new system. Must schools for the user personnel be organized and operated? What level and quantity of engineering support will be required, and how will it relate to a permanent service organization? The answers to both of these questions must be ascertained in a realistic, inclusive plan because their implementation requires augmentation of the work force and long-term training periods.

(4) In concluding the examination from the company's viewpoint, we ask, will this improve or affect the market position in this area of activity? There is nothing wrong with acceptance of a near-term distaste for a future, commanding position.

(5) What is the profit potential? It must be great enough to serve as a reward for the risks assumed.

(6) Will the company be best able to contribute to the defense of this country by engaging in the particular activity under scrutiny? Needless to say, if it cannot be done well, it is better to forget about it and do something that can be done properly, with distinction, and with dispatch.

Conclusion

We have concluded a microscopic examination of market intelligence and planning analysis. In summary, let us look at the planning problem in the macroscopic sense. There are five phases to the problem of planning new systems—*what*, *where*, *why*, *when*, and *how*. *What* is determined by the Service and the forward thinking of the business staff. *Where* is answered by a study of roles and missions and consideration of future strategy and tactics. *Why* is the test of the true validity of the *what*. *Why* is the most important and difficult of the five phases—"important" because, from a business sense, it is ultimately catastrophic to be committed to a needless task; "difficult" because it requires a detailed, correct forecast of future warfare and technology arrived at sometimes after brushing aside current opinions and technology. *When* is answered in a large measure during *why* and can be cross-checked by budget analyses, military plans, and intelligence estimates. *How* is dependent on your own engineering, manufacturing, and managerial skill and ingenuity. *What*, *where*, *why*, and *when* are answered for the most part during the intelligence gathering and evaluation. Only then can the problem be defined and a management plus engineering solution be synthesized. Thus we arrive at the planning payoff—*how*—and confidently set sail for the future.

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The author considers that solid-propellant and liquid-propellant rockets are best suited for guided-missile propulsion where reliability for one sure shot is demanded and that the air-breathing engines—the ram-jet and turbojet—are more effective when duration of burning is significant.

Guided-Missile Propulsion

T. J. Keating*
Wright Air Development Center

SOME YEARS AGO when gas turbines, ram-jets, pulse-jets, and rockets appeared on the military scene, the Power Plant Laboratory at Wright Field separated these as a matter of convenience into rotating and nonrotating engines—the former being turbine and piston engines and the latter, rockets, ram-jets, and pulse-jets. This schism was tantamount to a separation into piloted aircraft propulsion and guided-missile propulsion, for, at present, about 85 per cent of the workload in the nonrotating engine branch is on guided-missile propulsion. The rotating engine branch is the reverse.

In piloted aircraft application, the requirement for wide range of operations, long life, and thrust modulation is so high that lesser performance is acceptable. In guided-missile applications, however, advantage can be taken of the simplicity, compactness, and very high performance that can be obtained from ram-jets and rockets.

Ordinarily, a fixed thrust setting is quite acceptable and even desirable in a missile. True, there may be two levels of thrust in the trajectory—one for boost and one for cruise—but the transition from one to the other can be sharp and abrupt, permitting the use of two different single-thrust power plants. This is a matter of tremendous importance to rocket designers, for we know that liquid rockets are least reliable in any transition from one thrust level to the other. In steady state, they are very reliable. The solid rocket as presently conceived is either fixed or, at any rate, preprogrammed thrust. There is no attempt to throttle with mechanical contrivances. Any thrust modulation resulting from grain geometry is no less reliable than fixed thrust. The ram-jet, because it is an air-breathing engine, must have a control system, and it is a source of unreliability. So, to keep this unreliability to as low a point as possible, missile designers are wise in designing their missile to accommodate the ram-jet performance that results from the simplest control. This can be done by several methods, including methods for varying the missile drag. Thus, the missile speed is adjusted by a less fickle means than fuel flow modulation.

I do not want to imply that there is nothing to the art and science of controls in guided-missile propulsion. The ram-jet control, operating in a supersonic regime, has an unusually sophisticated task to perform. The criterion for acceptability is somewhat different, however, in that it involves more intimately the vehicle design.

This discussion points up a most profound difference in the development stage of guided-missile propulsion. Whereas the demands for long life and wide operating conditions for piloted aircraft application result in long hours of endurance running at fixed sea-level conditions in the development of turbojets, the demands for extraordinary reliability for one shot, or very short life, operation result in a much different development technique for guided-missile applications.

We have evolved a shakedown test technique that we call "peripheral testing" to establish reliability in our guided-missile propulsion. I will define the testing procedure in order to differentiate between this type of development program and the piloted aircraft application type.

Fig. 1 is a very generalized illustration of this point.

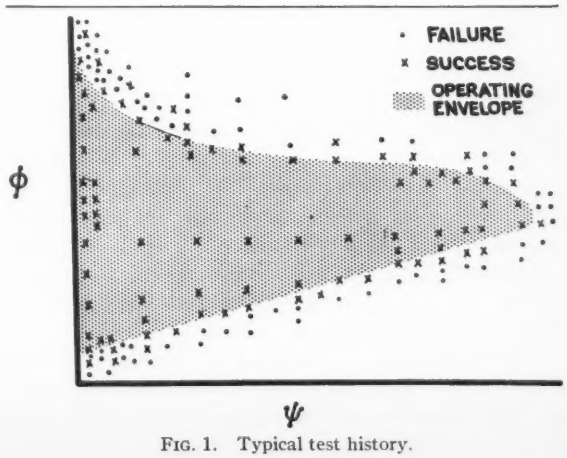

FIG. 1. Typical test history.

Presented at the Guided Missiles Session, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Power Plant Laboratory.

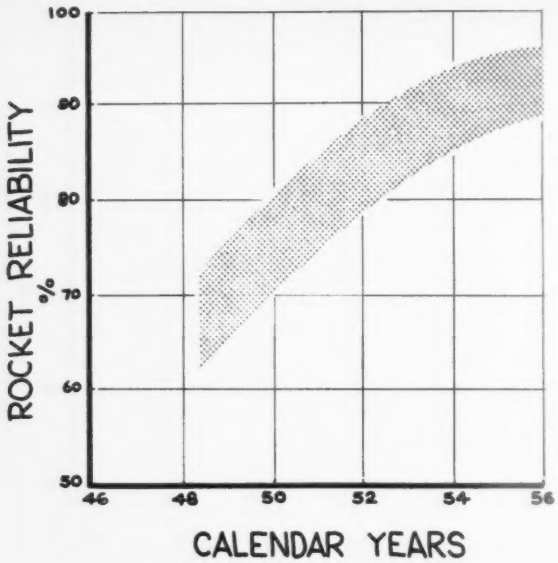

FIG. 2. Liquid-rocket engine reliability in flight test.

The crosses represent points of successful operation. The dots are points of attempted operation where failure resulted. The envelope chosen for guided-missile operation is well within the limits of successful operation that have been found in actual testing with as large a number of samples as is economically practical and timely. Notice here that we have replaced endurance at a few set conditions with many, many test points at different conditions. The different conditions could be environmental, dimensional tolerances, altitude, Mach Numbers, and any other influential conditions that will be imposed in military life—including storage conditions, by the way.

There seems to be nothing profound in this philosophy, but it took some time to adjust to it. This is a very expensive procedure. Ground test facilities are vastly more elaborate, and the numbers of hardware pieces required during the development phase are even more because this program is a statistical thing.

Moreover, one obviously cannot impose every conceivable condition and get statistically valid numbers at all those conditions. Fortunately, components are usually at least similar in several engine models, and their development histories are mutually supporting. The assessment of the state of the art for a new engine model, the availability of facilities, the time and money assigned to the program, and a host of other practical factors require consideration in planning a missile engine development program.

The solid rocket is the simplest propulsion device in aeronautical use and also the most reliable, bar none. It is so reliable and so classically a guided-missile power plant that we wish we could use it for all guided-missile applications. To illustrate its reliability, let us turn to the field of piloted aircraft and cite the statistics on JATO firings. JATO is the field of greatest usage to date, by far, of solid rockets for propulsion. The design principles are the same, and the data are therefore entirely applicable. Out of the hundreds of thousands of JATO bottle firings in the period since the last years of World War II, there have been reported less than ten failures and not one fatality. This outstanding record is precisely what we are seeking in the guided-missile field. One sure shot. Reliability is so overwhelmingly higher for solid rockets that all missile designers are urged to use them if they possibly can.

It turns out that there are some reasons why they cannot always use them. The main reasons are their utter inflexibility and their lower performance. Because a rocket carries its oxygen around with it, it is heavier than and noncompetitive with air-breathing engines for long-duration applications within the earth's atmosphere. The solid rocket is the poorer in this respect because its entire case is pressurized and therefore heavy. So, the longer the duration, the larger the tank and the less competitive the solid. Most solid guided-missile rockets have durations of less than 10 sec.

Because of their fixed thrust and short duration, solids are used for very short-range vehicles, such as air-to-air and air-to-surface missiles, or for boost in longer range vehicles which employ some other propulsion device for the cruise phase. In this latter case, the boost unit is separate and is jettisoned immediately upon burnout.

Another important advantage of the solid unit for a military organization is its storability in a state of readiness. Most solids can be stored under a wide range of climatic conditions for several years. They are easily transportable and require much less checkout equipment and technique than other power plants.

Despite the fact that the solid rocket is the oldest missile propulsion device, the history of development of the modern propellants is fairly meager. At the end of World War II, attention was focused on the liquid-rocket engine, probably because of the effect of the German V2 and the German rocket-powered fighters. It has been only in the last 5 years that there has been any considerable effort to develop and adapt large solids to guided missiles. In these years, the size has increased tenfold and the state of the art improved so that they are competitive in more and more areas of guided-missile propulsion.

One of the major advances has been in the technique of manufacturing large propellant grains by casting the composite grain in the engine case and so bonding the grain to the case which results in much better volumetric efficiency.

In the high-performance field, although there has been little apparent advance in propellants, an I_{sp} of 220 to 230 lb. sec. being obtainable some 10 years ago, there is a great deal of work being done to improve this figure; and temperature and pressure coefficients have been improved by considerable degrees. The rheological properties of propellants have been greatly improved, permitting the use of larger sized grains.

Considerable advances have been made in "hardware" design, two notable advances being the use of

high-tensile stretch formed cases and reinforced plastic cases.

Although the inherent simplicity and reliability of the solid-rocket engine has been stressed, there are many involved problems connected with its design and development. One of the major problems is a direct result of the high flame temperatures which are necessary in order to obtain high performance. The design of a pressure vessel, convergent-divergent nozzle, and, in some cases, a duct, capable of withstanding over 1,000 psi at 4,000 to 5,000°F., would be difficult in any field; but, when weight has to be at a minimum, the problem is intensified. Briefly, the major problems facing the designer can be listed by types of application.

In the case of boosts for guided-missile take-off, the weight of the boost engines is a higher proportion of the total all-up weight, often in excess of 50 per cent. The overall performance index of such boosts therefore has a large effect on missile performance. Fortunately, weight reduction can be achieved by reducing the factor of safety as the missiles are not man carrying. This cannot be carried too far as the high cost of guided missiles, damage to the launching area, and the importance of the target all require a high degree of reliability. By intensive development, rocket engines have been produced with satisfactory reliability factors in spite of the factor of safety on the engine case being less than 1.5 to 1 on the ultimate strength of the material.

Special problems have arisen with increased size. In order to have a good overall performance index, the density of loading of the propellant must be as high as possible. In order to achieve this high density of loading, the burning rate of the propellant must be high, and the state of the art is such that burning rates in excess of 1 in. per sec. are not readily available. This means that, with a conventional star-centered grain, the maximum diameter for a 3-sec. duration boost would be in the order of 15 in. A two-pronged attack is to develop high rates of burning propellants and to design grain shapes more sophisticated than the star center. These grain designs are often complicated and require considerable physical properties from the propellant.

There are also many internal ballistic problems and problems of nozzle design, both for performance and reliability. There are some applications where a solid-propellant rocket simply could not be made to do the job because of requirements for variable thrust, center-of-gravity control, and thrust vector control, and for just plain high performance.

Improvements in solid-propellant performance have been extraordinary in the past few years; however, the liquid-rocket engine has continued to improve and maintain its superiority in this respect. In a typical liquid-rocket engine, the turbopump assembly and the thrust-chamber assembly account for about 35 per cent of the total weight. Obviously, improvements in the thrust chamber and in the turbopump will have the greatest effect on the overall weight reduction for this liquid-rocket engine. In the past few years, turbopump output per unit weight has increased twofold, and thrust chamber output per unit weight has increased fourfold. These obviously have had striking effects on the output per unit weight of the total rocket engine. On top of this, utilization of higher performance liquid propellants is resulting in rather striking overall liquid-rocket engine performance figures today.

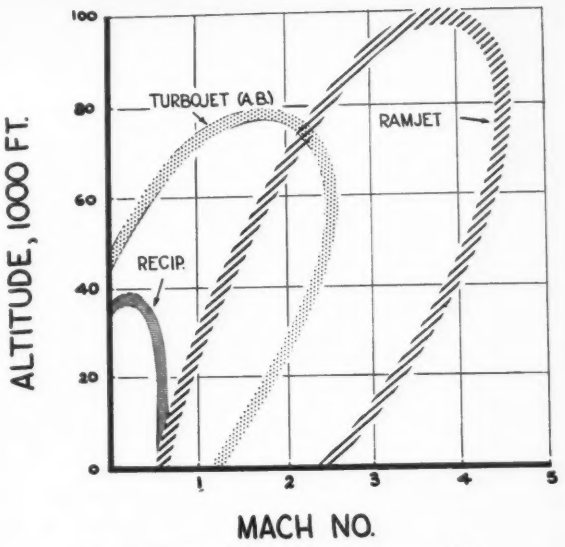

FIG. 3. Power-plant performance comparison.

I believe that the most interesting of all improvements in liquid-rocket engine characteristics has been the improvement in the engine reliability in these past few years. Fig. 2 gives us an impression of the recent improvement in reliability of these rockets. "Reliability," in rocket terminology, means the measure of the ability of the device to perform precisely as predicted on the very first try. This denies any restart attempts, so, when you consider the broad band of temperature operation that is desired on military devices, a 99.999 per cent reliability is an extraordinary demand. For example, I doubt very much if modern automobiles would stand up under such a demanding definition. However, to get back to the point at hand, Fig. 2 indicates a general increase in reliability through the past few years. The line is broad because of security and because there is such a wide variation between missiles that it is hard to average the conditions.

Leaving the discussion of rocket-type power plants, let us now consider the air-breathing engines—the ram-jet and turbojet. Since the operational use of the rocket is not generally comparable to the air-breathing engine, the basic comparison will be that of the ram-jet with the turbojet. These engines are best suited to guided-missile applications where duration of burning is significant. Therefore, SFC becomes an important parameter. Fig. 3 illustrates the regions of operation for air-breathing power plants based on comparable state of the art. The basic advantage of the ram-jet is its capability of high Mach Number, high-altitude operation, a characteristic extremely vital to military needs in maintaining weapon superiority. The range of

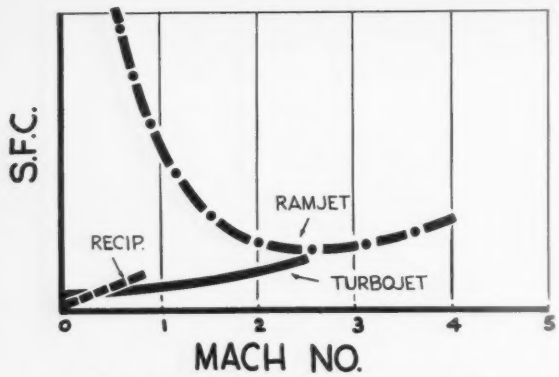

FIG. 4. Power-plant performance comparison.

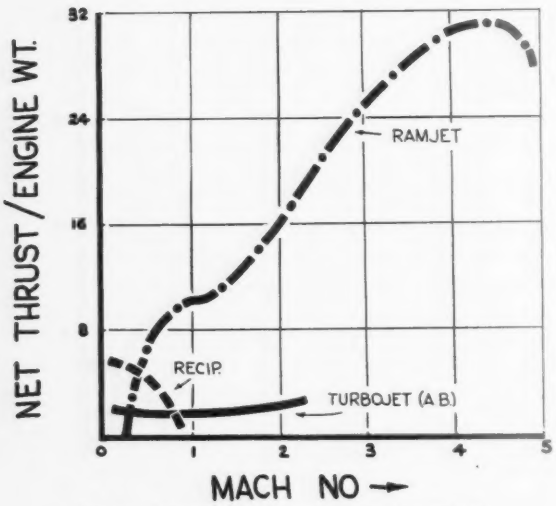

FIG. 5. Comparison of thrust vs. engine weight.

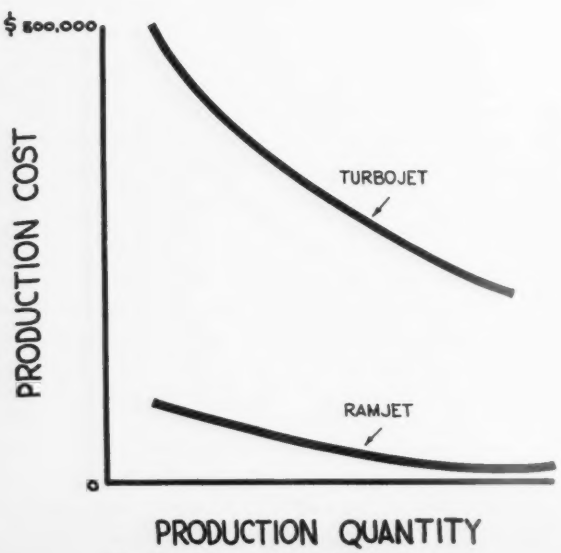

FIG. 6. Comparative production costs.

turbojet operation can be extended beyond that shown, but the development cost and time increase are significantly due to the problem of developing high-strength compressor sections capable of operation in the high Mach temperature environment.

As mentioned earlier, SFC and thrust/engine weight become significant parameters in evaluating the applicability of ram-jets and turbojets. Fig. 4 presents general values of SFC attainable. The turbojet possesses a decisive advantage in the lower M region and therefore generally dictates selection of the turbojet for this type of guided-missile application. As M is increased to approximately $M = 2.0$ and above, the SFC becomes increasingly less, indicating that other factors must be considered in selecting the optimum air-breathing power plant. These considerations are such factors as thrust/weight, operating region, reliability, cost, and development time. Fig. 5 depicts the thrust/engine-weight performance of these engines. Here the ram-jet shows a decided advantage with about an 8 to 1 advantage at $M = 2.0$ and increasing rapidly with M. Here again the basic simplicity of the ram-jet design is emphasized. This factor is also significant when engine reliability is considered, for the reduced complexity and even the number of components ease the momentous task of developing and demonstrating reliability.

Intuitively, one would expect the ram-jet engine—once described as only a "stovepipe"—to cost much less than the turbojet in production. Although full-scale ram-jet production has not yet been achieved, production analysis indicates a cost future as noted in Fig. 6. As anticipated, the ram-jet cost is as low as one-twelfth the cost of a turbojet. The natural learning curve trend is also indicated in that the learning curve on the more complex turbojet is steeper.

With the above performance comparison of ram-jet and turbojet, one must not omit the major drawback of the ram-jet engine—that is, the lack of low M thrust capability. This, of course, results from the basic design principle of using high-velocity air compression for the pressure increase instead of compressor machinery as in the turbojet. This drawback requires the weapon system to provide an initial means of guided-missile acceleration. For this purpose, the solid- or liquid-rocket launch might be used, or the launch might take place from a high-speed airplane.

Because of the number of factors which must be evaluated in selecting the proper air-breathing power plant or combination with the rocket engine, it is necessary to treat each guided-missile application individually to determine the optimum propulsion system. Many applications exist for both the ram-jet and the turbojet.

The major problem confronting ram-jet engine contractors today is that of adequate wind-tunnel facilities for the necessary research and development to take advantage of the stride in engine performance possible. The USAF is seriously considering this problem and taking those steps deemed necessary for its solution.

Vice-Adm. Charles E. Rosendahl, USN (Ret.)*
National Air Transport Coordinating Committee

Aircraft Noise as It Relates to the Airport Neighbor

The efforts that have been made by the civil air transport industry to alleviate the problems of noisy flight over people's homes.

PERHAPS SOME of you, as specialists in more glamorous phases of aeronautics, wonder why you should be interested in aircraft noise.

The aircraft is the composite product of the entire aeronautical profession. Hence, legal guardianship—and its responsibilities—for unwanted aircraft noise seems to me to rest, by and large, with the whole aeronautical profession. We are all in this together.

Despite all our efforts in their behalf, the industry occasionally still gets accused of lacking consideration for its airport neighbors. The very existence of the National Air Transport Coordinating Committee, of course, negates any such contention.

Let me acquaint you briefly with NATCC.

NATCC is made up of voluntary representation from literally every segment of the civil air transport industry. Our membership includes 16 air carriers and the Air Transport Association, Aircraft Industries Association, Air Line Pilots Association, Aircoach Transport Association, Aircraft Owners and Pilots Association, Airport Operators Council, American Association of Airport Executives, Civil Aeronautics Administration, Civil Aeronautics Board, Independent Military Air Transport Association, National Business Aircraft Association, and Port of New York Authority.

The NATCC approach has been two-pronged:

First, we have sought, within the limits of safety and of increasing technological ability, to reduce to an achievable minimum noisy flight over people's homes.

Second, we have sought to provide interested residents in airport areas with solid, factual information. This is to help them understand and evaluate the air industry's operations, from the standpoints of the practical aspects of flight, safety, annoyance, economic value, and defense value.

We carry out these two activities simultaneously but obviously with major emphasis on the noise problem.

Lacking satisfactory control of aircraft noise at its source—that is, the aircraft itself—the only practicable remedial measures of necessity are procedural in nature:

(1) We have devised and implemented a system of preferential runway usage. This involves conducting approach, landing, and take-off operations over water or open areas, whenever possible within those safety criteria which must surround prudent, safe operations.

(2) We have adopted procedures for the maintenance of maximum altitude for as long as possible before landing. To a large degree, this has eliminated low, dragging, power-on approaches over airport neighborhoods.

(3) We have determined that an accelerated climb-out to at least 1,200 ft., before turning on course, is more desirable from the noise standpoint than turns at relatively low altitudes.

In several areas, however, we have made exception to the straight-out climb procedure in order to take advantage of open terrain adjacent to the runway extensions. These special procedures utilize a turn as soon as practicable after take-off to permit the aircraft to conduct initial climb over the open areas.

(4) We have reduced the disturbance from ground engine run-ups by conducting these run-ups in areas removed from near-by residential sections and, as far as practicable, by utilizing existing airport structures as baffles.

(5) We have transferred from these metropolitan airports to open areas or to other more suitably located airports all transport training flights except those specifically required by federal regulation to be made at specific airports. This change has resulted in substantial relief to airport neighborhoods.

This one step has reduced the number of landings and take-offs so involved by well over 25,000 per year and

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Luncheon address, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

* Executive Director.

has eliminated at least twice as many low-level, high-power circling operations.

Our technical staff has improvements and refinements in our measures constantly under consideration.

Yet, nevertheless, we are still confronted with a substantial body of critical, determined, and sometimes emotional residents who demand more relief than we have been able to provide to date.

In short, our airport public is still not satisfied with *today's* noise situation, and it is decidedly perplexed and apprehensive of things to come with the advent of new types of aircraft having new propulsion systems. These residents pounce upon published and spoken reports from both industry and lay sources. They hear that noises from turbine-driven aircraft are different in character and greater in intensity than those of the piston power plants they now know.

Certainly no one in the aeronautical profession or in the industry would deny that turbojet power plants, in their *pristine* state, do produce noise that is different in character and greater in intensity.

The march to turbine power plants has been progressive, and, even at this early stage of the search for noise relief, the picture looks promising. Our experience with turboprop aircraft so far, and in the horsepowers and configurations currently in service, has been good. The airport neighbor, who is concerned primarily only with flight operations in his immediate vicinity, has no quarrel with turboprop aircraft.

But nature does not bestow all the superlatives on any one type of aircraft or indeed on any one form of transportation. So the march of progress cannot stop at the turboprop. To obtain the higher and higher speeds we want and need in aircraft, the next step requires that we must go on to the "pure jet" or turbojet propulsion system.

The turbojet aircraft is propelled not by propellers but by the thrust derived from the expulsion of extremely hot, expanding, and accelerating gases from the rear of its turbine engines. The resultant noise stems mainly from two sources. At the forward end of the turbojet engine, the air compressor spinning at very high r.p.m. tends to produce a high-pitched whine. The greater part of the total noise appears at the rear of the engine, where its high-temperature, high-velocity gas jet mixes turbulently with the surrounding air.

As far as my knowledge goes, the main efforts in mitigating the compressor whine are aimed at tuning it out, absorbing it in the intake passages, and—for ground run-ups—deflecting it upward. My best information is also that the engineers believe that, by a combination of methods, it can be accomplished satisfactorily at no severe penalty.

But the problem that currently appears the most difficult—if, as they must be, severe penalties in weight and drag are to be avoided—is the suppression or control of the noise at take-off and in early flight which arises from the turbulent mixing of the hot jet stream with the surrounding air.

The problem is being vigorously attacked by various groups and in various ways. It seems entirely probable that, in the sanctity of their own laboratories and workshops, other scientists and other engineers are working on solutions along other lines.

We have not yet actually been subjected to noise from civil jet transports, for the simple reason that in this country there are no such craft yet in service.

The impressions the public has of jet aircraft so far have had to come mainly from what it could see and read about such craft. Up to now, that has centered almost entirely around military jet aircraft. Also, the noisy villain in the military often is the afterburner, a device that will *not* be employed by civil jet transports.

The diagnosis of civil jet noise woes obviously has involved laborious and exacting determination of the how, when, and where of jet noise generation and its propagation to more distant points.

To date, announced orders for our two United States turbojet transports total less than 200. This figure will hardly grow significantly until service experience with them is gained. According to published information, earliest deliveries are about 3 years off. The others will flow from the factories at a fairly uniform rate for the succeeding 3 years so that the total of something under 200 in service is still some 6 years distant. Thus the impact of these new transports will be felt gradually.

The public has weighed well the words of carrier officials with respect to their optimism that the new aircraft will have noise characteristics satisfactory to our airport neighbors.

Upon what do these industry leaders base such optimism?

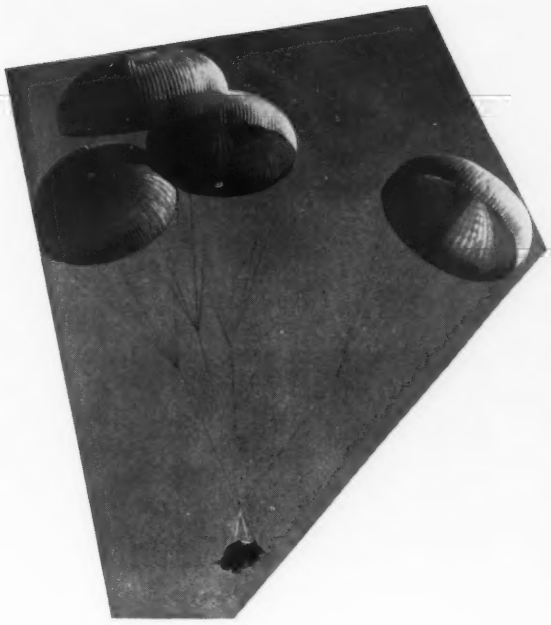
They know that from coast to coast hundreds of engineers are working day in and day out on these noise problems, that the feeling of engineers in the whole field of aeronautics is one of optimism, and that an industry which has brought man's aeronautical dreams of centuries into reality in only 50 years certainly has a great deal more up its sleeve.

The leading aeronautical research agency in the world is our own federally sponsored National Advisory Committee for Aeronautics. Its splendid Langley and Lewis research laboratories contribute immeasurably to such basic matters as this aircraft noise problem. The distinguished Director of NACA, Dr. Hugh L. Dryden, soberly and conservatively sums up the situation this way:

"The noise problem is difficult. However, continued research is expected to lead to further gains. The development of airplanes with acceptable noise levels will require a careful balance between the advantages of increased performance, the economic penalties associated with the noise alleviator, and the interests of the community."

I sincerely hope that both the industry and the airport public grasp the significant fact that this world leader in aeronautical research ranks "the interest of the community" as one of the three major considerations in this aircraft noise problem.

Helmut G. Heinrich*
Wright Air Development Center



Drag and Stability of Parachutes

The common types of parachutes are briefly described and illustrated, and the relationship between the effective drag of a parachute and its stability is explored.

Introduction

Parachutes are air-borne vehicles, and their trajectories as well as their static and dynamic forces must be predictable with a certain degree of accuracy. However, a parachute is a pilotless uncontrolled vehicle—a nonrigid structure made out of porous material. Because of these features, the stability behavior and the sinking speed are interrelated; the opening forces depend to a certain extent on the elasticity of the parachute materials, and the air density influences the inflation tendency, the stability, and the air resistance.

These interactions considerably complicate the prediction of the parachute performance. For example, in any trajectory calculation among the main parameters are the air resistance and the stability of the object. If one or both parameters depend on a third one, say on the velocity, any trajectory calculation becomes very inconvenient and time consuming.

The question is now whether or not, in the use of parachutes, such a dependency is strong enough that it has to be considered. The main objective of most parachute applications is, since Leonardo da Vinci, to land a weight with a certain impact velocity, the vertical component of the velocity being the most interesting characteristic. Because of its importance, the vertical velocity has been given a special name, "the rate of descent." Related to the rate of descent is the air resistance in the vertical direction. This resistance is called the effective drag. It should not be confused with the aerodynamic term "drag," which is the air resistance in the direction of the total velocity.

Deriving now, in the conventional fashion, a coefficient of effective drag C_v, one observes in Fig. 1 a surprisingly strong dependency of this coefficient on the rate of descent.

It may be said in advance that this variation is caused not by a Reynolds Number but by a stability effect be-

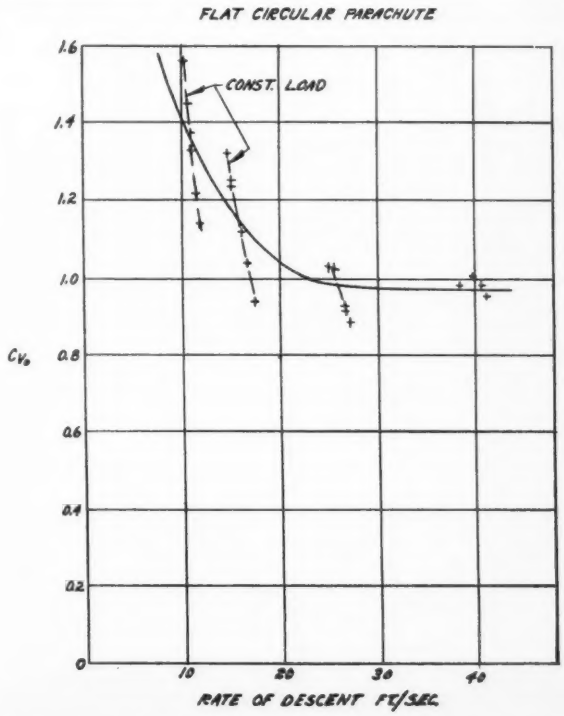


Fig. 1. Coefficient of the effective drag as function of the rate of descent (based on reference 1).

* Parachute Branch, Equipment Laboratory.

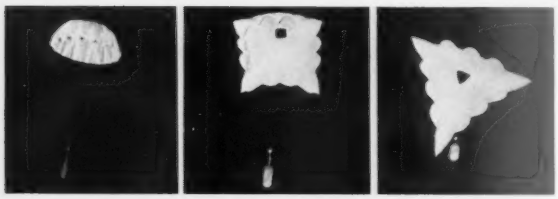


FIG. 2. Various types of solid flat parachutes: *left*, circular; *middle*, square; *right*, triangular.

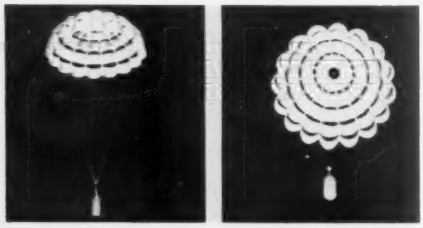


FIG. 3. Circular ringslot parachute.

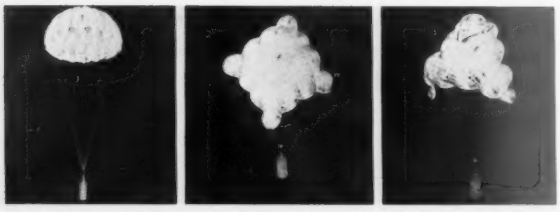


FIG. 4. Various ribbon parachutes: *left*, circular; *middle*, square; *right*, triangular.

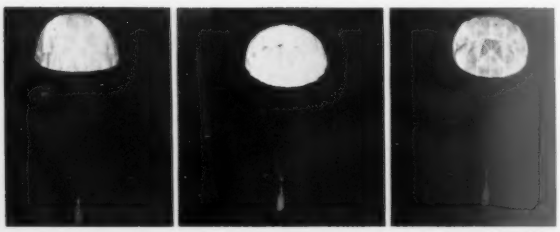


FIG. 5. Formed gore parachutes: *left*, spherical; *middle*, parabolic; *right*, extended skirt.

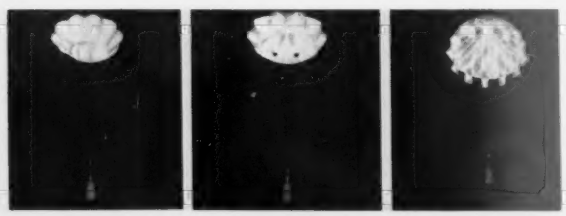


FIG. 6. The basic types of guide surface parachutes: *left*, stabilization; *middle*, universal; *right*, personnel.

cause the effective drag of parachutes with identical stability behavior does not vary appreciably over a wide range of Reynolds Number, whereas the same types of parachutes show a strong change of effective drag over a small range of Reynolds Number when their stability behavior varies. Therefore, one may conclude that the effective drag of a parachute depends primarily on its stability, and this relationship shall be the subject of the following discussion.

THE COMMON TYPES OF PARACHUTES

In connection with Figs. 2–9, the main types of the presently known parachutes shall be briefly described. The solid flat parachutes with medium porosity are all unstable; they either oscillate, glide, or perform a combined motion. The ringslot parachutes with considerably high porosity are more stable than any of the medium porosity parachutes. The ribbon parachutes belong to the same family, and their geometric porosity is of the same order as that of ringslot parachutes; however, the individual units of material and open space are smaller, and the stability of ribbon parachutes is in general better than that of the ringslot parachutes. The formed gore parachutes attempt to influence the parachute behavior by shaping the canopy. They are characterized by the drawn-in skirt, and they are generally more stable than the comparable flat parachutes with the same porosity.

In the design of the guide surface parachutes, the concept of parachute shaping has been carried considerably farther. They are made of low-porosity cloth, and they are characterized by a conical surface at the lower portion of the canopy. The guide surface parachutes are the most stable parachutes in their respective classes, and they are specialized for stabilization of bombs, mines, and torpedoes (stabilization type); for the recovery of guided missiles and escape capsules

FIG. 7. The conventional 28-ft. circular flat personnel parachute for bail-out speeds up to 250 knots. (USAF-type C9.)

(universal type); and for rescue of men from high-speed aircraft (personnel type).

These are only the more common types of parachutes. There are numerous other types with other minor variations.

Stability

In the preceding paragraphs, it has been mentioned that the various parachutes display different stability characteristics, and, in free descent, the longitudinal axis of each parachute assumes a particular angle between the trajectory and the vertical. This is obviously the angle of attack at which the load, suspended by the parachute, and the aerodynamic forces are in equilibrium.

Fig. 10 shows the equilibrium conditions in general terms.

In steady descent, the resultant of the lift and drag forces is numercially equal to and coincides with the force vector of the weight. From this equilibrium, it follows that the total velocity depends on the coefficients of lift and drag which are functions of the angle of attack. Since the vertical velocity, or the rate of descent, is merely a projection of the total velocity, one recognizes that the rate of descent is a direct function of the angle of attack related to the stable position.

In view of this, the wide variation of the effective drag shown in Fig. 1 could be understood if one and the same parachute had several stable positions or if its drag and lift coefficients varied for the same angle of attack. To pursue these two problems, one may turn to wind-tunnel studies.

The combination of a weight and a parachute which moves under the influence of only drag, inertia, and gravitational forces may be compared with a so-called ballistic missile which flies without lift forces. In view of the objective of parachute drops, an ideal parachute moves like a ballistic missile, and, because of this similarity, the methods used in ballistics may be adopted for investigations of parachutes.

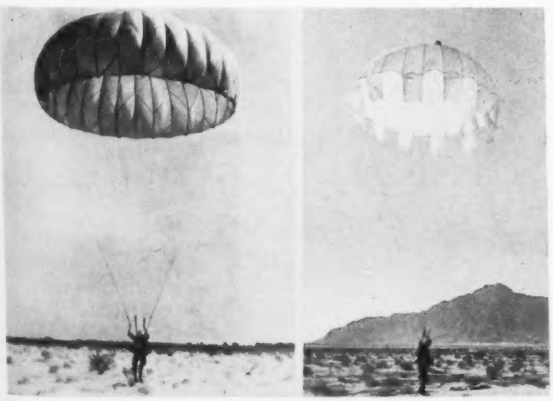


Fig. 8 (*left*). The extended skirt parachute used by the Airborne Troops. (USAF-type T10.) Fig. 9 (*right*). The personnel guide surface parachute for bail-out speeds of 375 knots at sea level. (USAF-type C10.)

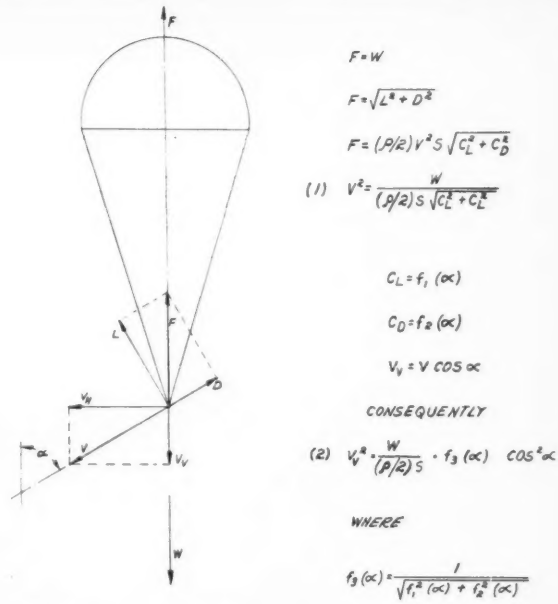


Fig. 10. The rate of descent as function of the stable position.

In ballistics, it is customary to define a moment which tends to reduce any deflection from zero angle of attack as positive stability. Such a moment is also called stabilizing moment. The stability is usually expressed in the moment coefficient $C_M = M/(\rho/2 V^2 SD)$ as function of the angle of attack. In a similar manner, one defines the coefficients of the tangential and normal forces $C_T = T/(\rho/2 V^2 S)$ and $C_N = N/(\rho/2 V^2 S)$.

Since it is difficult to measure on nonrigid parachute models aerodynamic forces at various angles of attack, one may, in the first approach, use simulated rigid parachute models and introduce later the corrections for the effects of aeroelasticity. Figs. 11 and 12 show the results of wind-tunnel measurements with four models which resemble the four typical parachutes—namely, a solid flat, a slotted high porosity, a ribbon, and a guide surface parachute.

Since for steady descent the resultant air force must coincide with the suspended weight, these parachutes will descend with an angle of attack at which the coefficients C_N and C_M are zero. Therefore, parachutes 1, 2, and 3 will move with a resultant angle of attack of 45°, 35°, and 15°, respectively. The guide surface parachute in Fig. 12 will descend vertically. It is important to note that the curves of the moment and the side force of these parachutes indicate only one stable position which angular magnitude varies for the different types.

These experiments were made with idealized models. The next step in wind-tunnel technique is the use of textile models which incorporate the flexibility and the porosity of the cloth, and Figs. 13–15 show the difference in the characteristics of idealized and real parachute models.

General information on parachute performance can also be obtained from drop tests in an enclosed hangar

if all movements of the parachute models can be recorded by theodolite cameras. However, this method is expensive and time consuming and does not provide the aerodynamic coefficients as obtained from wind-tunnel measurements.

Most parachutes are too large to be investigated in regular wind tunnels, and the next best method of testing actual parachutes is either to tow them by means of a sled or to drop them with a fin-stabilized test vehicle. Both methods have been used, and the results agree in general very well with the results of the wind-tunnel experiments. Figs. 16 and 17 show the arrangement and results obtained by the Cook Research Laboratories, Chicago, on a rocket-propelled sled and on a fin-stabilized missile.[4] The parachutes had, in all cases, approximately 6.5-ft. inflated diameters. The results agree in principle with those obtained in wind-tunnel measurements.

In summary, one may state that conventional parachutes have statically only one stable position. This position ranges from 0° in guide surface parachutes up to 45° in nonporous solid flat parachutes. The effective drag of a parachute depends on its stable position, but the wide variation of the effective drag cannot be explained through the static stability alone. A detailed study of the parachute drag may provide further information.

Drag

Fig. 18 shows that, for a steady glide, the effective drag is merely a function of the tangential force and the angle of the stable position.

The freely moving parachute assumes this angle α either in a steady glide, in a coning motion, or in a motion combined from gliding and coning. From these three types of motion, only the steady glide is a motion with a steady aerodynamic flow pattern. In the other two motions, fields of low and high pressure are revolving around the canopy with the rhythm of the coning.

The gliding parachute can be compared with a parachute model in a wind-tunnel experiment with an adjusted angle of attack. Therefore, the results of such wind-tunnel tests may be compared with those of tests with actual parachutes under gliding condition.

Fig. 11 shows that the nonporous hemisphere is stable at $\alpha = 45°$, with $C_T = 1.7$ and $C_N = C_M = 0$. In accordance with these figures, a nonporous hemispherical parachute would glide under 45° with $C_v = (C_T/\cos^2 \alpha) = 3.4$. These figures are related to the projected areas

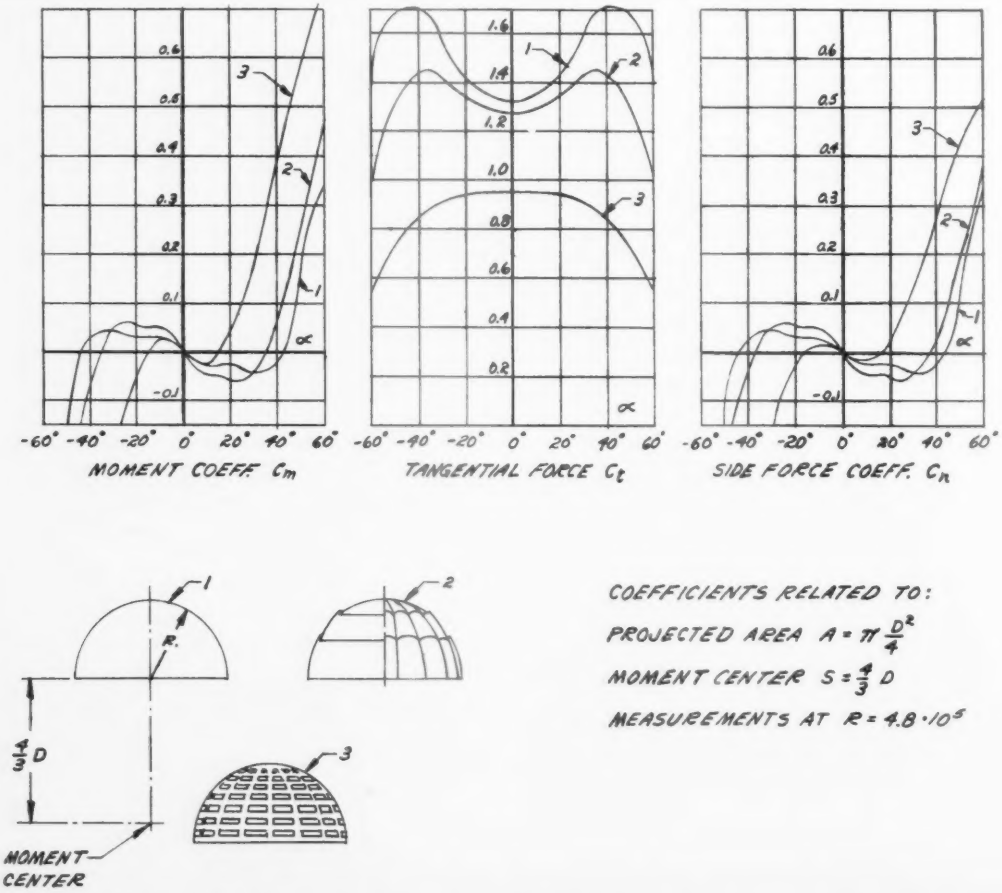


Fig. 11. The aerodynamic coefficients of models of a nonporous solid flat, a nonporous slotted, and a ribbon parachute with 35 per cent geometric porosity.[2]

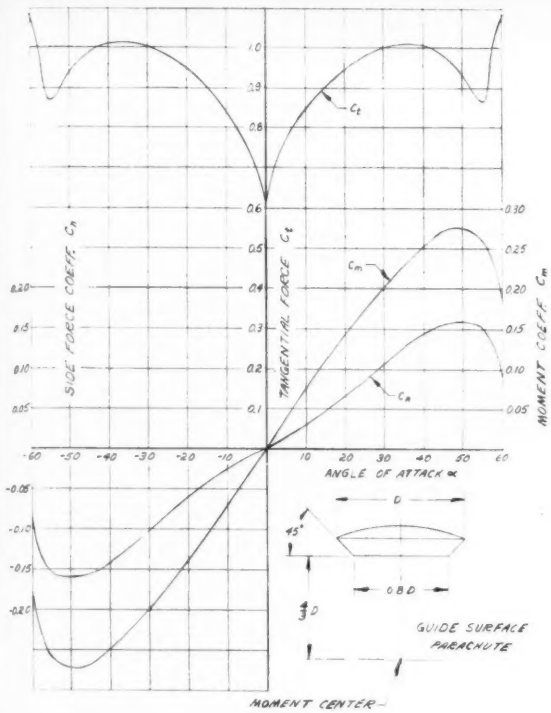


FIG. 12. The aerodynamic coefficients of a model of a nonporous guide surface parachute.[2]

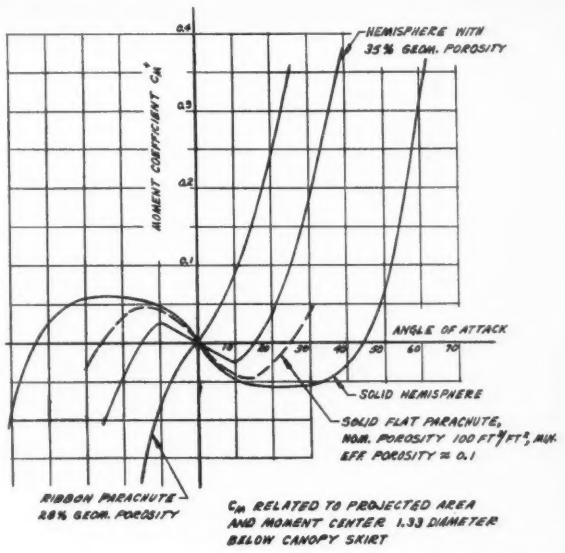

HEMISPHERE WITH 35% GEOM. POROSITY
MOMENT COEFFICIENT C_M^*
ANGLE OF ATTACK
SOLID HEMISPHERE
SOLID FLAT PARACHUTE, NOM. POROSITY 100 FT³/FT², MIN. EFF. POROSITY ≈ 0.1
RIBBON PARACHUTE 28% GEOM. POROSITY
C_M RELATED TO PROJECTED AREA AND MOMENT CENTER 1.33 DIAMETER BELOW CANOPY SKIRT

FIG. 13. Moment coefficients of rigid and nonporous and flexible and porous parachute models.

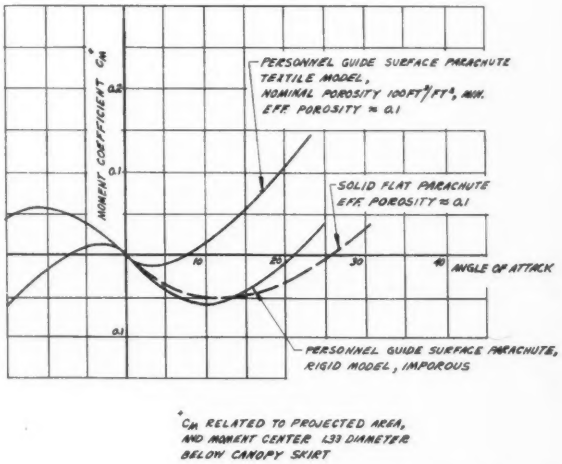

PERSONNEL GUIDE SURFACE PARACHUTE TEXTILE MODEL, NOMINAL POROSITY 100 FT³/FT², MIN. EFF. POROSITY ≈ 0.1
SOLID FLAT PARACHUTE EFF. POROSITY ≈ 0.1
MOMENT COEFFICIENT C_M^*
ANGLE OF ATTACK
PERSONNEL GUIDE SURFACE PARACHUTE, RIGID MODEL, IMPOROUS
C_M RELATED TO PROJECTED AREA, AND MOMENT CENTER 1.33 DIAMETER BELOW CANOPY SKIRT

FIG. 15. Moment coefficients of rigid and nonporous and flexible and porous personnel guide surface parachute.[3]

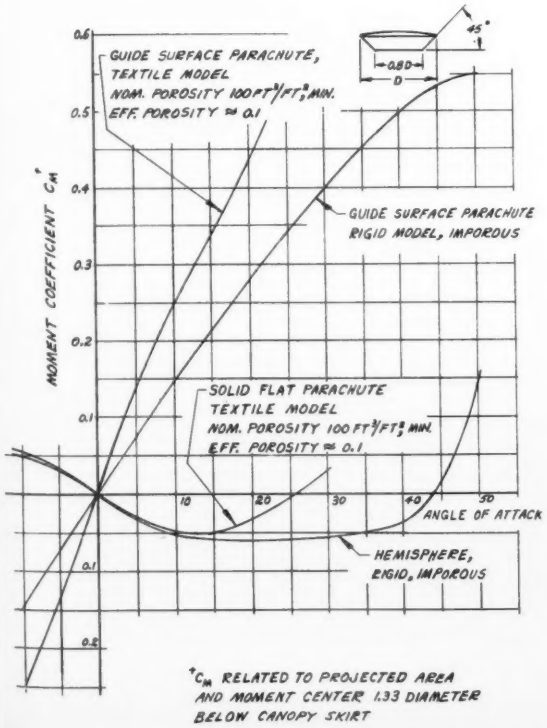

GUIDE SURFACE PARACHUTE, TEXTILE MODEL NOM. POROSITY 100 FT³/FT², MIN. EFF. POROSITY ≈ 0.1
GUIDE SURFACE PARACHUTE RIGID MODEL, IMPOROUS
SOLID FLAT PARACHUTE TEXTILE MODEL NOM. POROSITY 100 FT³/FT², MIN. EFF. POROSITY ≈ 0.1
HEMISPHERE, RIGID, IMPOROUS
MOMENT COEFFICIENT C_M^*
ANGLE OF ATTACK
45°
0.8D
D
C_M RELATED TO PROJECTED AREA AND MOMENT CENTER 1.33 DIAMETER BELOW CANOPY SKIRT

FIG. 14. Moment coefficients of rigid and nonporous and flexible and porous guide surface parachute models.

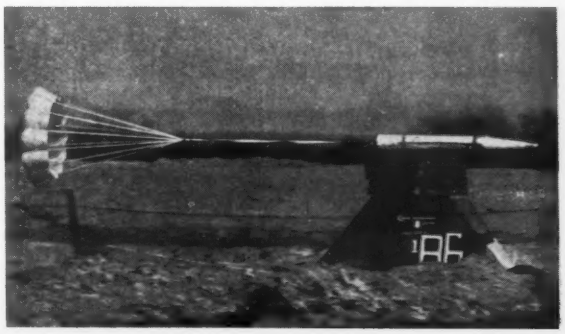
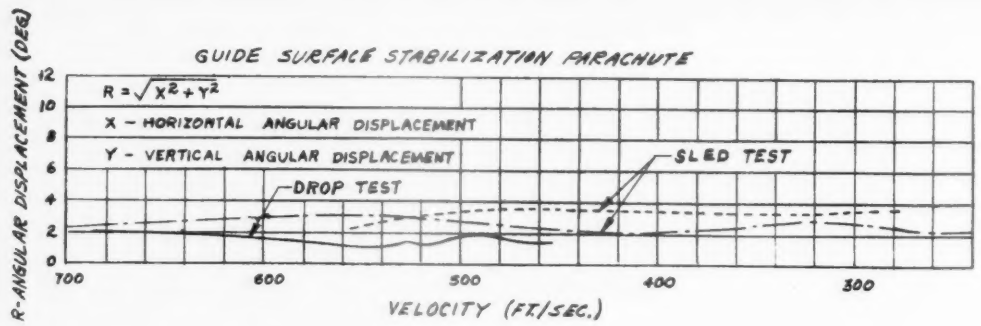
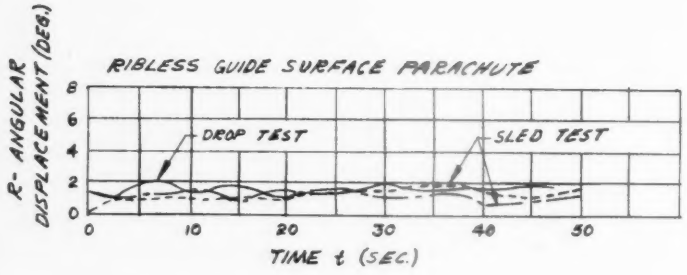
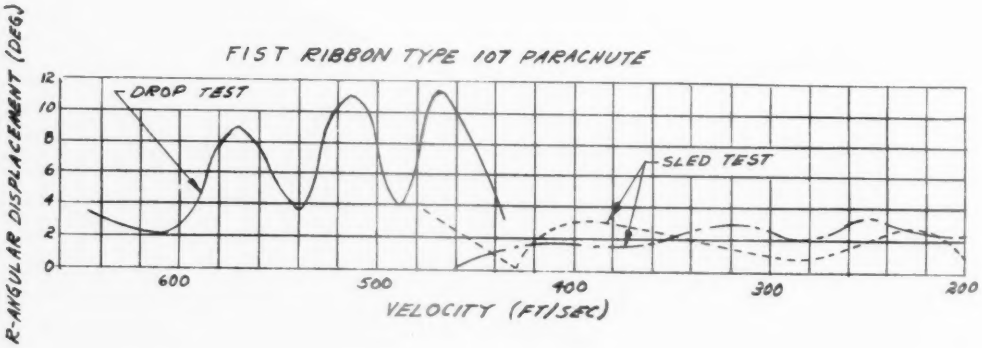


FIG. 16. Guide surface parachute towed by a rocket-propelled instrumented sled.[4]







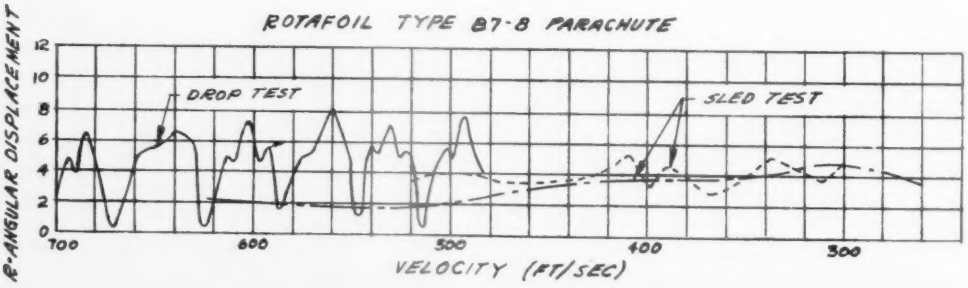


FIG. 17. Results of experiments with a sled and a fin-stabilized drop test vehicle.[4]

$S = \pi(D^2/4)$. In parachute technique, it is customary to relate all coefficients to the total cloth areas S_0; in this case $S_0 \approx (9/4)S$. Therefore, the coefficients of effective drag of a solid hemisphere amounts to $C_{v_0} = 1.51$.

Ross and Stimmler,[1] Goodyear Aircraft Corporation, found in hangar tests for solid flat parachutes of 12-ft. diameter, which primarily performed a gliding motion, values in the order of $C_{v_0} = 1.5$. In live jumps with steerable parachutes where an extended glide was the main objective, values of $C_{v_0} = 1.15$ have been recorded.

Considering that the steerable parachutes were made of porous cloth and had, in addition, slots and holes whereas the wind-tunnel models were rigid and nonporous, one may say that wind-tunnel experiments, model drop tests, and live jumps agree very well and that the high C_{v_0} values of Fig. 1 are related to gliding parachutes.

One may now postulate that the low C_{v_0} values of Fig. 1 belong to coning parachutes. In the first approximations, a coning or oscillating parachute adjusts itself to the same angle of attack. However, because of the transverse motion of the canopy with respect to the airflow, the zones of separation and attachment of the flow of the canopy are not necessarily the same as for the gliding parachute. Therefore, one has to expect a variation of the aerodynamic coefficients depending on the gliding or coning motion of the parachute. Experiments show that oscillating or coning parachutes have a lower effective drag than the same parachutes under gliding conditions.

This creates the question: When does a parachute glide and when does it cone or oscillate? In principle, this is a matter of dynamic stability; in practice, one and the same parachute glides at a low ratio of weight per unit of projected area of the canopy. This ratio is called the load figure. At a high load figure, the same parachute usually cones or oscillates.

The transition from one state to the other varies with the different types and, to a certain extent, with the size of the parachute. For example, in a considerably small range of load figure, a statically unstable solid flat parachute markedly changes its stability behavior whereas the statically stable guide surface parachute descends practically vertically, independent of load figure. This is understandable because one of the requirements of dynamic stability is the stability under static conditions. Because of this difference in stability behavior, statically unstable parachutes change their effective drag considerably while stable parachutes have practically a constant effective drag.

The majority of the presently used parachutes are statically unstable. Therefore, it has become customary to state the coefficient of effective drag as function of the rate of descent. The rate of descent is merely another expression of the load figure. In the previously cited work by Ross and Stimmler, the authors recorded the relationship between effective drag and gliding or coning for a number of parachute models. Table 1 and

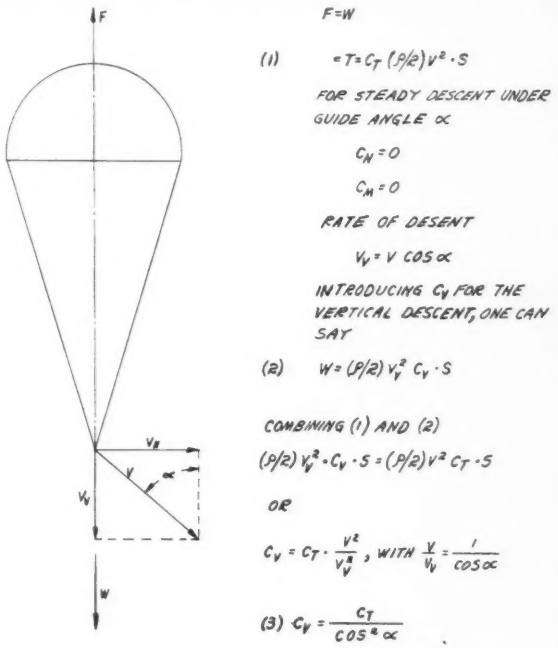

F
W
V_H
V
V_V
F=W
(1) $= T = C_T (\rho/2) V^2 \cdot S$
FOR STEADY DESCENT UNDER GUIDE ANGLE α
$C_N = 0$
$C_M = 0$
RATE OF DESENT
$V_V = V \cos\alpha$
INTRODUCING C_V FOR THE VERTICAL DESCENT, ONE CAN SAY
(2) $W = (\rho/2) V_V^2 C_V \cdot S$
COMBINING (1) AND (2)
$(\rho/2) V_V^2 \cdot C_V \cdot S = (\rho/2) V^2 C_T \cdot S$
OR
$C_V = C_T \cdot \frac{V^2}{V_V^2}$, WITH $\frac{V}{V_V} = \frac{1}{\cos\alpha}$
(3) $C_V = \frac{C_T}{\cos^2\alpha}$

FIG. 18. The coefficient of the effective drag as function of the coefficient of the tangential force and angle of the stable position.

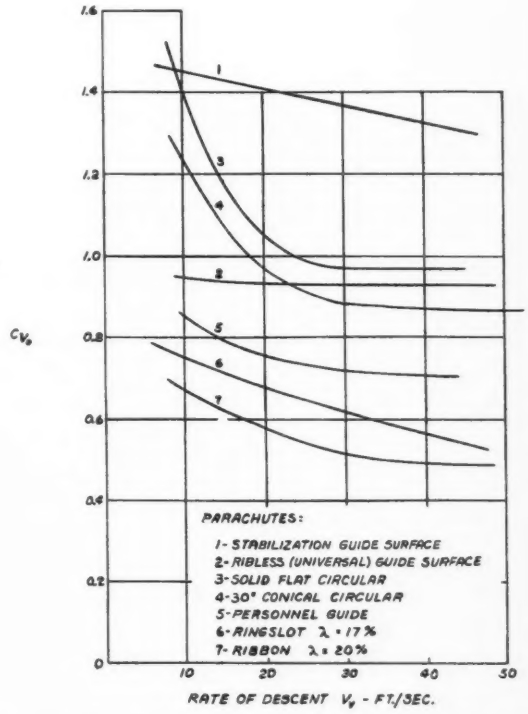


FIG. 19. The coefficient of the effective drag as function of the rate of descent of various types of parachutes.

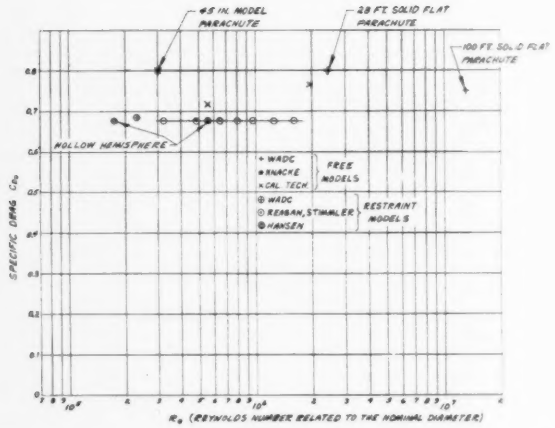


FIG. 20. Coefficient of effective drag of circular solid flat parachutes vs. Reynolds Number.[3]

TABLE 1
Effective Drag vs. Rate of Descent of Various Parachute Models[1]

	PARACHUTES								
	FLAT CIRCULAR			30° CONICAL CIRCUL.			PERSONNEL GUIDE		
V_e	C_{V_0}	γ_{av}	α_{av}	C_{V_0}	γ_{av}	α_{av}	C_{V_0}	γ_{av}	α_{av}
10	1.40	37	16	1.24	32	17	0.85	18	10
15	1.17	30	23	1.08	26	16	0.8	19	15
25	0.98	8	28	0.91	12	30	0.74	10	22
40	0.97	6	28	0.87	6	26	0.71	6	20

	RING SLOT λ=17%			RIBBON CIRCUL. λ=20%		
10	0.75	14	10	0.68	9	5
15	0.71	9	13	0.62	7	5
25	0.65	6	6	0.54	3	3
40	0.57	4	4	0.43	5	0

	GUIDE SURFACE STABILIZATION			GUIDE SURFACE RIBLESS		
10	C_V 1.48	13	16	C_D 0.94	11	8
15	1.43	4	11	0.94	6	12
25	1.39	4	11	0.93	3	4
40	1.34	5	2	0.93	3	3

$C_{V_0} = \frac{2W}{\rho V_0^2 A_{TOTAL}}$

$C_V = \frac{2W}{\rho V_T^2 A_{PROJECTED}}$

γ_{av} = AVERAGE GLIDE ANGLE

α_{av} = AVERAGE ANGLE OF OSCILLATION

V_e = RATE OF DESCENT

TABLE 2
Coefficients of Effective Drag of Actual Parachutes

	RATE OF DESCENT FT/SEC.			
	15	20	30	600
PARACHUTE	C_{D_0}			
FLAT CIRCULAR	0.85	0.75	0.65	
FLAT EXTENDED SKIRT (10%)	0.85	0.80	0.75	
PERSONNEL GUIDE CHUTE		0.72		
RINGSLOT λ = 17%		0.65		0.60
RIBBON λ = 17%		0.55		0.50
ROTAFOIL				0.78
	C_D			
STABILIZATION GUIDE CHUTE		1.2		1.0
RIBLESS GUIDE CHUTE		0.85		0.8

TABLE 3
Coefficients of Effective Drag of Single and Clustered 100-Ft. Parachutes

100 FT. FLAT CIRCULAR PARACHUTE, SINGLE AND IN CLUSTERS

	RATE OF DESCENT FT/SEC.	
	< 25	25–30
NUMBER OF PARACHUTES	RESULTANT C_{D_0} *	
1	0.76	0.74
2	0.75	0.66
3	0.73	0.62
4	0.70	0.58

* AVERAGE VALUES

Fig. 19 show the principal results of these experiments.

One may now suspect that the Reynolds Number causes these variations. However, the coefficient of effective drag of solid flat parachutes obtained at approximately the same rate of descent and identical stability behavior do not show a characteristic change over a range of $R = 1.5 \cdot 10^5$ to $1.3 \cdot 10^7$. (See Fig. 20.)

The preceding considerations are based mostly on studies with parachute models. The effective drag of actual parachutes is of the same order and is shown in Table 2. These values are obtained from experiments performed under the direction of the Wright Air Development Center.

For the delivery of a very heavy load, it is advisable to arrange moderately sized parachutes in clusters rather than to increase the size of a single parachute to the required magnitude. Such a cluster arrangement is shown in Fig. 21,* and the related performance values are given in Table 3.

* Headpiece, p. 73, depicts aerial delivery with clustered 100-ft. solid flat parachutes.

Conclusion

From the preceding considerations, one may conclude that the effective drag of statically unstable parachutes varies strongly with the rate of descent, the reason being a dynamic instability primarily caused by insufficient static stability. Statically stable parachutes are to a high degree also dynamically stable and show merely an insignificant variation of effective drag.

References

[1] Stimmler, F. J., and Ross, R. S., *Drop Tests of 16,000 sq.-in. Model Parachutes*, USAF Tech. Rep. 5867, 1954.

[2] Heinrich, H. G., *Untersuchung über die Stabilität von Fallschirmen und Entwicklung eines stabilen Fallschirmes aus normal durchlässigem Stoff*, Zentral für Wissenschaftliches Berichtswesen (ZWB), F. B., 1780, 1943.

[3] Heinrich, H. G., *Aerodynamics, Performance, and Design of Personnel Guide Parachutes*, USAF M.R.-WCEE-672-145-A-9-1, 1951.

[4] *Recovery of Guided Missiles and Target Aircraft*, USAF Tech. Rep. 5853.

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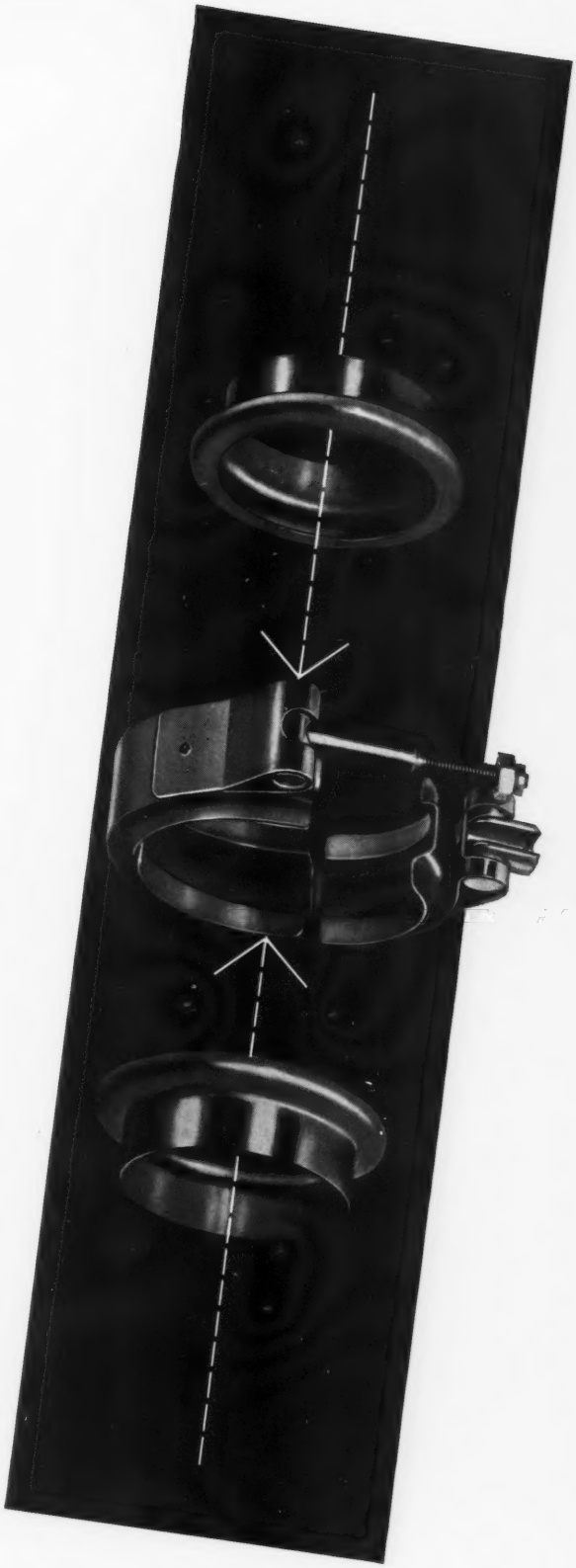

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IAS News

(*Continued from page 39*)

▸**Clinton R. Hanna** (M), Associate Director of the Westinghouse Research Laboratories, has won the Benjamin Garver Lamme Medal for 1955. The American Institute of Electrical Engineers chose Dr. Hanna "for his fundamental calculations and developments in the field of electrodynamics, and particularly for his achievements in the design of voltage regulators, automatic rolling-mill controls, and tank gun stabilizers."

▸**Darrol N. Harris** (M), of Shell Oil Company, has been named to the NACA's Subcommittee on Aircraft Fuels.

▸**Kenneth R. Herman** (M), President of Vickers Incorporated, has been elected First Vice-President of The Engineering Society of Detroit.

▸**Dan A. Kimball** (AM), President of Aerojet-General Corporation and former Secretary of the Navy, was to be the speaker at Commencement exercises of Iowa Wesleyan College on June 4. He was to receive an honorary degree of Doctor of Laws.

▸**William F. Milliken, Jr.** (M), Manager of Flight Research at Cornell Aeronautical Laboratory, Inc., has been appointed to the NACA's new Subcommittee on Aerodynamic Stability and Control.

▸**Wayne W. Parrish** (AM), Editor and Publisher of the American Aviation Publications, has been presented the Paul Tissandier Diploma by the Fédération Aéronautique Internationale.

▸**Frank N. Piasecki** (F), President of Piasecki Aircraft Corporation, has been honored by the City Council of Philadelphia for "his significant contributions to aeronautical science, national defense, the city's economy, and the cause of human freedom." The last item in the resolution passed by the Council referred to Mr. Piasecki's leadership of a group of Philadelphians of Polish descent in organizing the Pulaski Transport Line. This company placed in operation the merchant ship "Wolna Polska" ("Free Poland"), manned by Polish seamen who had escaped from behind the Iron Curtain. The "Wolna Polska" completed its maiden voyage at Philadelphia on March 5.

Herbert K. Weiss, AFIAS, Chief of Northrop's Weapon Systems Analysis Dept., has been reappointed to the National Technical Advisory Panel on Ordnance of the Department of Defense.

Courtland D. Perkins, AFIAS, Chairman of the Dept. of Aeronautical Engineering at Princeton, has been named Chief Scientist of the U.S. Air Force. He succeeds H. Guyford Stever, AFIAS, of M.I.T.

▸**David A. Richardson** (M), Chief Project Engineer for Preliminary Design, Vertol Aircraft Corporation, has been appointed to the NACA's Subcommittee on Icing Problems.

▸**Lt. Col. Robert R. Scott, USAF** (TM), has been awarded a certificate by the Fédération Aéronautique Internationale in recognition of the nonstop speed record he established March 9, 1955, from Los Angeles to New York. Flying a Republic F-84F Thunderstreak, he flew 2,464 statute miles in 3 hours 46 min. 33 sec. at an average speed of 652 m.p.h. Colonel Scott shared the honor with Republic Aviation Corporation, which also received a certificate.

▸**Charles M. Seibel** (M), Chief Engineer of the Helicopter Division, Cessna Aircraft Company, has been named to the NACA's Subcommittee on Helicopters.

▸**Maurice A. Sulkin** (M), Chief Thermodynamicist, North American Aviation, Inc., has been appointed to the NACA's Subcommittee on Compressors and Turbines.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

D. Barker Bates (M) has been placed in charge of the new Industrial Design Section of the Engineering Division of Canadair Limited, Montreal, P.Q.

John Boshar (M) has been promoted to Loads and Dynamics Department Engineer at the Georgia Division of Lockheed Aircraft Corporation.

Paul H. Bremer (M) has been promoted to the newly established position of Chief Structural Engineer of the Georgia Division, Lockheed Aircraft Corporation.

Jack M. Brower (M) has joined Aerojet-General Corporation, Azusa, Calif., as a Design Engineer in the Aerodynamics and Weapon System Group. Formerly, he was employed as a Senior Aerodynamicist in the Guided Missile Division of The Firestone Tire and Rubber Company, Los Angeles

William A. Clegern (M) has been appointed Manager—Marketing of the Jet Engine Department, Aircraft Gas Turbine Division, General Electric Company, Cincinnati. He was formerly Manager of the San Antonio, Tex., office of Convair, A Division of General Dynamics Corporation.

William C. Coulbourn (M) has been appointed Sales Manager of the Gyromechanisms Division of Norden-Ketay Corporation, Halesite, Long Island, N.Y. He was formerly Liaison Engineer of the Norden Laboratories Division.

Lt. Gen. Laurence C. Craigie, USAF (Ret.) (AF), who joined Hydro-Aire, Inc., last July as a Vice-President and Director, has been named Vice-President for Engineering.

Thomas A. Knowles, AFIAS, has been elected President of Goodyear Aircraft Corp. A graduate of M.I.T., he joined the company in 1927 and became Sales Manager in 1941. He has been a Vice-President since 1944.

THIS IS FOR YOU ... IF YOU HAVE AN AC GENERATOR COOLING PROBLEM!

SPECIFICATIONS

208/120 Volts, 0.75 Power Factor, 3 Phase, 400 CPS

Type No.	Rating KVA	Rated Cooling Air Pressure in "H_2O"	Rated Cooling Air lb./min.	Diam. in.	Speed RPM	Approx. Weight lbs.	Flange and Drive Spline
*28E16-1	20	4	11	8.25	5700-6300	60	AND 10266 XVI-A
*28B23-1	20	4	11	8.25	4800-7200	65	AND 10262 XII-A
*28E17-1	30	8	14	8.25	5700-6300	69	AND 10266 XVI-A
*28E14-1	40	5	14.5	9.25	5700-6300	83	AND 10266 XVI-A
*28E15-1	60	6	16	9.25	5700-6300	103	AND 10266 XVI-A
28E19-1	10	4	7	6.5	7600-8400	30	AND 10262 XII-A
28E19-3	10	4	7	6.5	7600-8400	31	New 9" Flange
28E20-1	20	6	8.5	6.5	7600-8400	45	AND 10262 XII-A
28E20-3	20	6	8.5	6.5	7600-8400	46	New 9" Flange
28E21-1	30	10	12.4	6.5	7600-8400	60	AND 10262 XII-A
28E21-3	30	10	12.4	6.5	7600-8400	61	New 9" Flange
**28E10-1	9	6	8.6	6.5	7600-8400	39	AND 10262 XII-A

*These generators include integral fan permitting full load continuously up to 80°C at sea level with no additional cooling.

**This generator incorporates a DC output of 30 volts, 50 amps capacity in addition to the AC output.

All generators have been designed to MIL-G-6099 and MS-33542, which specifies cooling air of 120°C at sea level, 40°C at 50,000 ft., and −12°C at 65,000 ft., and will deliver full-rated load under these conditions.

Bendix Red Bank

HIGH-TEMPERATURE AC GENERATORS

meet military class C air-cooled specifications ... offer maximum performance at minimum size and weight... range from 9 KVA to 60 KVA

These generators are designed as part of complete Red Bank high-temperature AC generating systems that also include magnetic amplifier voltage regulators and system protection components. For full details, write Red Bank Division, Bendix Aviation Corporation, Eatontown, New Jersey.

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West Coast Sales and Service: 117 E. Providencia Ave., Burbank, Calif.
Canadian Distributor: Aviation Electric Ltd., P.O. Box 6102, Montreal, P.Q.
Export Sales and Service: Bendix International Division, 205 E. 42nd St., New York 17, N.Y.

ENGINEERS WANTED: Opportunities now available for experienced design engineers to work on aircraft type AC and DC rotary power supplies and associated control equipment and distribution systems. Write today: Attention of Personnel Department K.

A. Wilson Laird, MIAS, formerly Vice-President of The New York Air Brake Co. in charge of Aviation Sales, has been named Vice-President in charge of Government Relations.

Kach Derdiarian (TM) has joined Consolidated Diesel-Electric Corporation, Stamford, Conn., as Chief of Technical Services. He was formerly a standards engineer with Lockheed Aircraft Corporation, Burbank, Calif.

J. A. Dilworth (AF), formerly of Consulair, Fort Worth, Tex., has joined the Georgia Division of Lockheed Aircraft Corporation as Structural Requirements Division Engineer.

Shepard Dudley (M) has been elected a Vice-President of Esso Export Corporation, New York. He will continue to manage Esso Export's International Aviation Sales Department. An old-time flier, Mr. Dudley joined the company in 1948.

Louis Fahnestock (M), who joined the company in 1931, has been named Director of Projects Administration of Fairchild Aircraft Division, Hagerstown, Md. He was formerly Director of Engineering.

Fred H. Felberg (M) has been promoted to Associate Director of the Southern California Cooperative Wind Tunnel at California Institute of Technology, Pasadena, Calif.

M. C. Haddon (M), formerly Chief Project Engineer, has been appointed Chief Engineer of Lockheed Aircraft Corporation's California Division.

Paul Helweg (M) has been named Liaison Engineer of the Norden Laboratories Division of Norden-Ketay Corporation, White Plains, N.Y. He was formerly Contracts Manager of the Instrument and Systems Division.

Charles H. Hurkamp (AF) has joined the Engineering Department of Fairchild Aircraft Division, Hagerstown, Md., as Chief of Advanced Design. He was formerly Chief Helicopter Engineer of McDonnell Aircraft Corporation.

Captain Roy Jackson, USN (Ret.) (M), has joined the management staff of Farnsworth Electronics Company, a Division of International Telephone and Telegraph Corporation, in Fort Wayne, Ind. He is responsible for expediting major research and development projects into production. Before retiring from the Navy, Captain Jackson was Director of the Maintenance Division of the Bureau of Aeronautics.

Clarence L. Johnson (F) has been elected Vice-President for Research and Development, Lockheed Aircraft Corporation. The position is newly established. Mr. Johnson was previously Chief Engineer of the California Division, He joined the company in 1933 as its sixth engineer.

Walter Koch (M) has joined the Aerophysics Development Corporation, Santa Monica, Calif., to work on the company's missile research program. A former Assistant Professor of Aeronautical Engineering at Cornell University, he has recently been a scientific consultant for Headquarters, U.S. Air Force in Europe, and a special representative in Germany for the Curtiss-Wright Corporation.

Charles R. Mercer (M) has been placed in charge of the new Airline Operations Engineering Department of Lockheed Aircraft Corporation. He has headed the Flight Engineering and Flight Operations Training Department since 1945.

William L. Mustard (AM), formerly District Manager in Dayton, Ohio, has been appointed Manager of the Field Service Department of Link Aviation, Inc., Binghamton, N.Y.

H. A. Parker (TM), formerly Flight Test Analysis Engineer, has been transferred to the staff of the new Airline Operations Engineering Department at Lockheed Aircraft Corporation.

S. J. Pipitone (TM) has been named Manager of the Design Analysis Department of Goodyear Aircraft Corporation, Akron, Ohio. He was formerly Manager of Air-Frame Installations Design.

George M. Rouzee (M) has been named Sales Manager of the new Special Missile Systems Division of Sperry Gyroscope Company Division of Sperry Rand Corporation. Mr. Rouzee, who was a Navy fighter pilot during World War II, has been Sperry's Manager of Navy Contracts since 1951.

John G. Sladkus (TM) has joined the Jet Engine Department Marketing Section, Aircraft Gas Turbine Division, General Electric Company, Cincinnati. Formerly in the Army, he was assigned to the Engineering Research and Development Laboratories at Fort Belvoir, Va.

R. W. Rummel, MIAS, formerly Chief Engineer of Trans World Airlines, Inc., has been elected Vice-President in charge of Engineering.

R. Allen Price, AFIAS, has rejoined Stanley Aviation Corp., Denver, as Vice-President for Sales and Service. For the past few years he has been with Parsons Corp.

Josiah E. Smith (M) has resigned as Associate Director of the Southern California Cooperative Wind Tunnel to join the Guided Missiles Research Division of the Ramo-Wooldridge Corporation, Los Angeles.

Randall C. Smith (AF) has joined Fairchild Aircraft Division, Hagerstown, Md., as Chief of Technical Engineering. For the past 10 years, he has been with East Coast Aeronautics, Inc., as Chief of Structures and Chief Engineer.

R. Dixon Speas (AF) has been retained by Slick Airways as a consultant on operating problems.

Conrad C. Wan (M) has joined Lockheed Missile Systems Division, Van Nuys, Calif., as a laboratory chief in the Systems Analysis and Evaluation Department. He was formerly a design project engineer with Chance Vought Aircraft, Inc., Dallas, Tex.

Harold H. Warden (M) has joined Link Aviation, Inc., Binghamton, N.Y., as Commercial Sales Manager. He was formerly General Sales Manager of the Propeller Division of Curtiss-Wright Corporation.

John B. Wassall (M), formerly Assistant Chief Engineer of Lockheed Aircraft Corporation, has been promoted to a newly created position, Director of Engineering.

Will W. White (AF), a former Vice-President of Esso Export Corporation, has been elected a Vice-President of Esso Research and Engineering Company, New York. Previously, as a Brigadier General in the Air Force, he was Staff Director of the Petroleum Logistics Division in the Office of the Assistant Secretary of Defense (Supply and Logistics).

William F. Whitesides (M) has joined Flight Refueling, Inc., Baltimore, as Engi-

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DESIGN

MAKING special motors and linear and rotary actuators is our only business. We make nothing else.

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neering Manager. He was formerly a Power Plant Design Engineer with Douglas Aircraft Company, Inc., El Segundo, Calif.

William W. Wood, Jr. (M), formerly Vice-President for Engineering, has been named Vice-President in charge of Manufacturing by Link Aviation, Inc.

Jack Wright (AM), formerly Sales Manager, has been promoted to Assistant Manager of the Aero Engineering Division of The Garrett Corporation.

CORPORATE MEMBER NEWS

• **Aerophysics Development Corporation** has begun construction of a $1,600,000 research facility on a 104-acre site in Santa Barbara, Calif. President William Bollay, FIAS, turned the first spadeful of dirt to break ground for an engineering building with 56,120 sq.ft. of floor space and a research building with 45,000 sq.ft. By late fall the company will move from Santa Monica to Santa Barbara. Now employing 450 persons, the company has doubled its staff since becoming a subsidiary of Studebaker-Packard Corporation in 1954.

• **Aircraft Radio Corporation . . .** A miniature automatic direction finder (radio compass) weighing 19.1 lbs. is now in production after a year of flight testing. Known as Type 21, the new ADF unit is a 3-band superheterodyne receiver, complete with power unit, receiver, control unit, indicator, loop, loop housing, and all connectors. It is designed for use in all types of aircraft. Type 21 provides reception of and direction on low-frequency range and broadcast stations in the 190- to 1,750-kc. spectrum. The unit has provision for compensation of as much as 25° of compass error from local field distortion. It contains 14 subminiature vacuum tubes. Sensitivity and selectivity, the manufacturer claims, compare favorably with that of equipment presently used in commercial and military aircraft and weighing three times as much. The low-frequency ADF is especially suitable for low-altitude flying where line-of-sight is restricted. It can be used in the vicinity of airports that have only low-frequency and/or broadcast facilities. Type 21 can be used as primary navigation equipment in a light plane or teamed with VOR and a lightweight VHF communication system in a larger plane.

• **Aluminum Company of America** has changed the name of its light-metals-research facility at New Kensington, Pa., from Aluminum Research Laboratories to Alcoa Research Laboratories. The name change was prompted by broadening activities of the research branch, which confined its activities to the study of aluminum when it was founded in 1918. New facilities for ultrasonic inspection and for fatigue-testing aluminum alloys at elevated temperatures have been installed at the laboratory.

• **American Airlines, Inc. . . .** Nonstop transcontinental air-coach service with DC-7's carrying 85 passengers is planned for the New York–Los Angeles and the Washington–Los Angeles runs. With a fare of $99, seats will be reserved and meals sold. . . . Using DC-6A's, American has started a new air-freight service between New York and San Francisco. . . . The annual report for 1955 shows American Airlines set two records for the air transport industry: passengers carried during the year exceeded 7,300,000, and freight ton-miles ran to 69,483,000. . . . A new division has been formed in the Operations Department to make plans to meet operating and service requirements connected with the introduction of new transports such as the turboprop Lockheed Electra and the turbojet Boeing 707. . . . J. B. Montgomery, a former Major General in the Air Force who joined the company a year ago, has been promoted to Vice-President for Maintenance and Engineering. . . . Manly Fleischmann, an attorney of Buffalo, has been elected to the Board of Directors.

• **Beech Aircraft Corporation . . .** The Missile Engineering Division has perfected a supersonic aerial tow target for air-to-air and surface-to-air gunnery training. Called the Dart, it is 12 ft. long and constructed of a 3-in. steel tube and four triangular plywood fins, mounted cruciformly at the rear. A refinement of a design developed by the Navy 2 years ago, the Dart has four radar reflectors which make it possible for ground or air-borne radar systems to "lock on" during tracking, gunnery, rocketry, and missile-firing missions. Optional models permit the installation of a smoke generator for visual identification or the use of frangible materials so that the target would break up when hit by gunfire. In Air Force tests, the Darts have been pulled through dives, turns, and other evasive maneuvers by F-86H jet fighters, with F-86's and F-100's in pursuit. The Dart is not intended to replace sleeve and banner targets. After fighter pilots have practiced with the relatively slow targets, they would progress to the faster Darts to test their marksmanship at maximum performance.

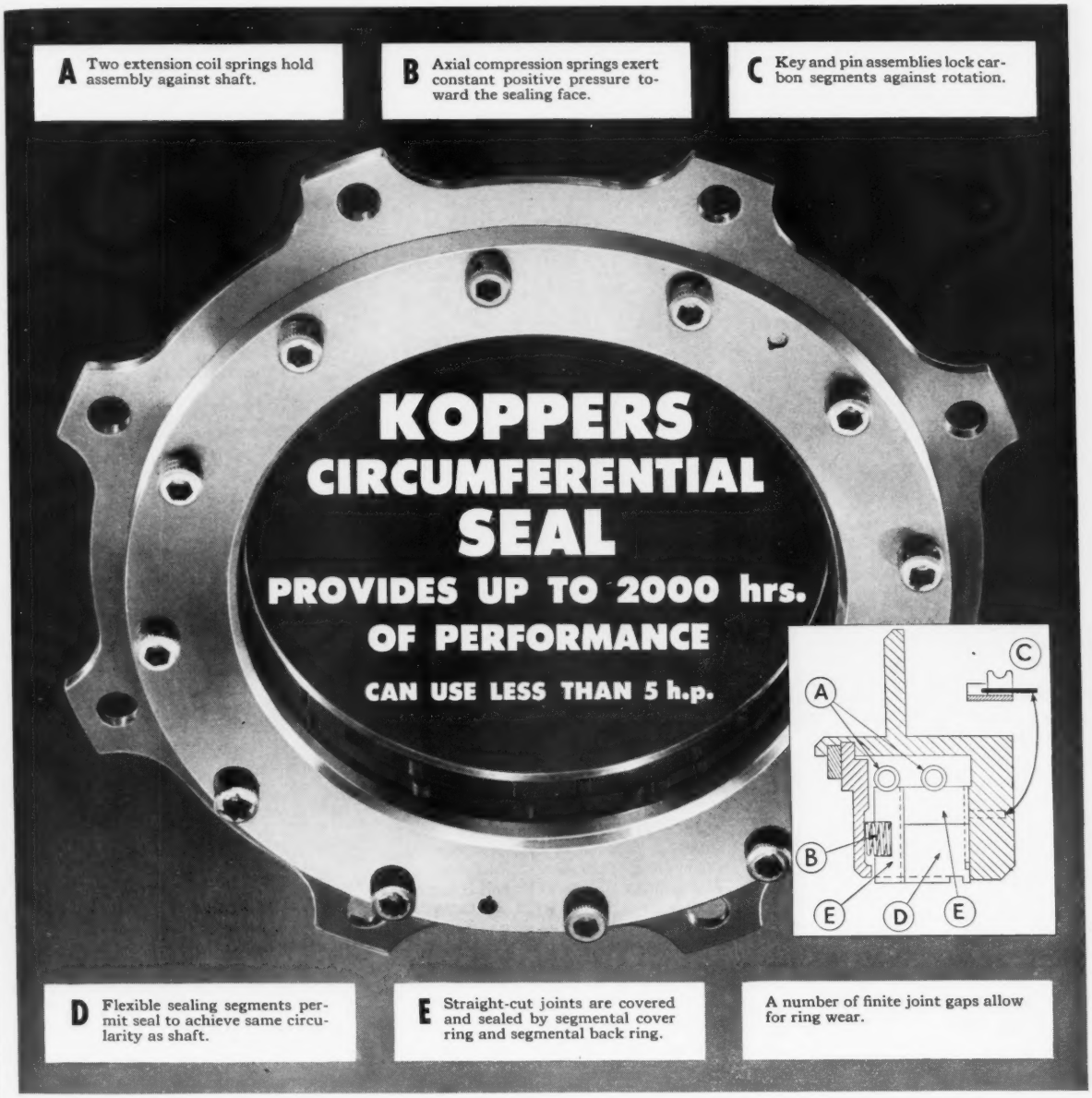
• **Bell Aircraft Corporation** has formed a Nuclear Engineering Department at its plant in Buffalo.

• **Bendix Aviation Corporation** is constructing two new facilities at Palmdale, Calif., to serve the booming aeronautical industry and network of military air fields in the Mojave desert and adjacent Antelope Valley. The new building of the Bendix Products Division, covering 5,600 sq.ft., will contain shop and test facilities for fuel-metering and landing-gear equipment. The Utica Division's building will have 2,000 sq.ft. devoted to servicing and testing combustion starters and air-turbine accessories. The buildings are on a 9½-acre plot adjacent to the Southern Pacific Railway. . . . The Bendix Pacific Division announces the development of a new air motor for use in missiles. Designed to operate an alternator and a hydraulic pump for an electrohydraulic supply to power a missile-control system, the new motor weighs 1½ lbs. and is fabricated of aluminum, except for blades and bearings. It is a constant-displacement, rotary-vane type. The air motor develops 2¾ hp. per 100 lbs. per sq.in. of inlet pressure. It performs satisfactorily with inlet pressure of 300 lbs. per sq.in. The motor has been qualified for missile applications over an ambient range of −20° to 160°F. and with accelerations up to 60*g*'s. It can withstand an inlet gas temperature of 1,000°F. for 2 min.

• **Bristol Aero-Engines Limited . . .** A marine version of the Bristol Proteus turboprop engine used in the Bristol Britannia air liner is being developed, in collaboration with the British Admiralty, to power high-speed patrol boats. The engine has completed 500 hours' running under simulated sea-going conditions. Salt spray was found to cause no permanent damage, and salt encrusted on the compressor blades can be washed off in 5 min. The marine version will weigh 3,000 lbs., develop 3,500 s.hp., and accelerate from idling to maximum power in 20 to 30 sec. Its outstanding advantage for use in patrol boats is its high power/weight ratio. In addition, the Bristol free-turbine principle enables the engine to be operated over a wide range of speeds and permits indefinite running at zero power.

• **Convair, A Division of General Dynamics Corporation . . .** The Skylark 600, a medium-range jet transport that Convair says will be the "fastest commercial airplane in the world," has been announced for delivery in 1960 at a price of approximately $3,300,000. Designed to cruise at 609 m.p.h. and to operate from 5,000-ft. runways, the sweptwing four-engined plane will be powered by the new General Electric CJ-805 jet engine, a commercial version of the J79. More than 100 American cities have airports adequate for the Skylark 600, according to Convair. In its pressurized, air-conditioned cabin, the Skylark will carry 80 first-class passengers or 99 coach passengers. The plane will have a wing span of 118 ft. 4 in., producing 2,000 sq.ft. of lifting surface for short-field take-offs and landings. The fuselage will be 118 ft. 5 in. long. Gross weight will be 170,000 lbs. The engines will be mounted on pylons beneath the wings. Intended primarily for trips between 500 and 1,500 miles, the Skylark will normally cruise at 35,000 ft. (See photo, p. 90.)

• **Fairchild Camera and Instrument Corporation . . .** The KB-5 motion-picture gun camera, developed for the Air Research and Development Command, automatically adjusts its lens opening to compensate for varying light conditions. With present gun cameras, the pilot chooses a setting for "bright," "dull," or "hazy" conditions, but he has no time to readjust the camera for quickly changing light conditions during combat. Much of the aerial film used has been improperly exposed. The automatic light control is expected to improve the quality of the film by ensuring correct


A Two extension coil springs hold assembly against shaft.
B Axial compression springs exert constant positive pressure toward the sealing face.
C Key and pin assemblies lock carbon segments against rotation.
KOPPERS
CIRCUMFERENTIAL
SEAL
PROVIDES UP TO 2000 hrs.
OF PERFORMANCE
CAN USE LESS THAN 5 h.p.
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D Flexible sealing segments permit seal to achieve same circularity as shaft.
E Straight-cut joints are covered and sealed by segmental cover ring and segmental back ring.
A number of finite joint gaps allow for ring wear.

Koppers Circumferential Seal is a segmented carbon seal ring with straight-cut joints. Its design can be modified to use step type joints or step seal joints. Primarily a gas seal, the Koppers Circumferential Seal will seal liquids if the geometry of the shaft mating faces is changed.

Koppers Circumferential Seals are one of a large variety of seals designed and manufactured by Koppers for every industrial use. Because of this complete line, Koppers can recommend, without bias, the seal best suited to your specific application. And Koppers continuous development and testing of new designs and new materials assure you of the most advanced, most efficient seals for your purpose. If you have a sealing problem, write to the KOPPERS COMPANY, INC., Metal Products Division, Piston Ring and Seal Department, 2206 Scott St., Baltimore 3, Maryland.

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KOPPERS

MECHANICAL SHAFT SEALS

Convair's new jet air liner, the Skylark 600, will have a wing span of 118 ft. 4 in. and fuselage length of 118 ft. 5 in. The 35° swept wing has 2,000 sq.ft. of lifting surface. Convair's Skylark 600 has been designed to carry 80 first-class passengers or 99 coach passengers at a cruising speed of 609 m.p.h. The new medium-range transport will be powered by four General Electric CJ-805 turbojets mounted on pylons. It will operate from 5,000-ft. runways. Normal cruising altitude will be 40,000 ft. The Skylark will sell for about $3,300,000.

exposure at all times. It compensates for light changes during combat and corrects itself without the pilot's attention. A neon light shines at a constant intensity on the camera shutter, which is coated with selenium. The reaction of the light on the selenium sets up an electrical impulse. At the same time, sunlight enters through the camera lens and shines on the selenium-coated shutter, setting up a second electrical impulse. The impulse set up by the neon light is constant, but the impulse set up by the sunlight varies as the light on the subject varies. A miniature computer inside the camera picks up these two impulses and compares them 64 times per sec. If the impulses are not equal, the computer adjusts the lens opening to admit more or less light until the two impulses match. At that point, the film is properly exposed. The Fairchild KB-5 camera is so rapid that it can adjust through its seven lens openings—f/2.8, 4, 5.6, 8, 11, 16 and 22—to an accuracy of within one-half stop in 1.8 sec. Film can be run at 16, 32, or 64 frames per sec., but the shutter speed is permanently set at 1/250 sec. The camera uses the standard 50-ft. cartridge of 16-mm. film.

• **Fairchild Engine and Airplane Corporation . . .** The Navy announced recently that some of its patrol planes have been equipped with the Petrel, a new guided missile that automatically searches out and destroys enemy ships at long range. The Petrel is manufactured by Fairchild's Guided Missiles Division in Wyandanch, N.Y., which formerly produced the Lark. The new Navy missile is designed to be launched by patrol planes well out of range of the antiaircraft batteries of enemy ships. It attacks at high speed and with devastating effect, sparing the pilot the risk of closing in on the target. The Petrel is one of the Navy's more complex missiles, both electronically and dynamically. In extensive testing and evaluation, first by the Bureau of Ordnance at the Naval Ordnance Test Station, Chincoteague, Va., and later by the Fleet Operational Development Force, the missile performed "with a degree of reliability considered exceptionally high for such a sophisticated weapon," the Navy said.

• **Federal Telecommunication Laboratories,** a Division of International Telephone and Telegraph Corporation, has established a California branch at the edge of Los Angeles, in the northern San Fernando valley. The first of five buildings has been erected on a 13-acre tract. The California laboratory will develop inertial air navigation systems, digital computers for aircraft, and air-borne electronic systems.

• **Fletcher Aviation Corporation** announces a modification of its FU-24 agricultural plane, making it suitable for passenger or cargo use. In the new model, the cabin space now occupied by a hopper filled with seed or fertilizer will contain two wide seats facing each other. One seat can be removed when the plane is used for cargo. The new FU-24 carries four passengers, plus the pilot, or a cargo load of 1,500 lbs. It has a 225-hp. engine and cruises at 110 m.p.h.

• **Flight Refueling, Inc.,** is conducting a study of high-speed aerial refueling for the Navy. It involves analytical, wind-tunnel, and flight-test work.

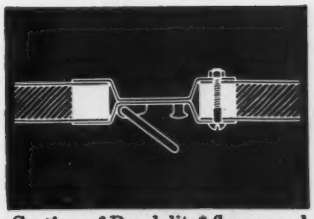
• **General Electric Company . . .** A commercial version of the J79 jet engine will be produced by the Aircraft Gas Turbine Division in Evendale, Ohio. The new CJ-805 engine, G-E claims, will have "more thrust per lb. of engine weight than any other engine in its power class." Four CJ-805's will be used to power Convair's new medium-range jet air liner, the Skylark 600. Specifications of the new engine were not disclosed. Since building America's first jet engine in 1941, the announcement said, G-E has produced more than 31,000 jet engines for the military services. . . . Thirty-five aircraft with Admiral Byrd's expedition to the South Pole are outfitted with G-E MA-1 gyrocompass systems, according to a company news release. . . . The Light Military Electronic Equipment Department has opened an office at 220 Dawson St., Seattle.

• **Jack & Heintz, Inc.,** has purchased two plants in Bedford Heights, Ohio, which will be used as an integrated research and development center. Occupied by Jack & Heintz for several years under lease agreements, the buildings have a floor area of 135,000 sq.ft. The research center will be staffed to design the complex electric systems required by advanced aircraft and missiles and will be equipped to build prototypes quickly, the company said. . . . Jack & Heintz is expanding activities connected with its design and production of inverters for the commercial air lines. Three modifications incorporating new 3,000-va. d.c. brush rigging have been developed for the F45-5 2,500-va. inverter. The company also is making kits available so that air lines may convert present J&H F45-5 inverters to the 3,000-va. rating. These inverter developments will make possible a simple expansion of present a.c. electric systems aboard commercial aircraft to include radar and other special a.c. devices. With the higher rated machines, this expansion can be accomplished without costly elaboration on present power installations.

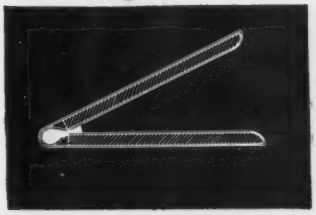
• **The Liquidometer Corporation** is constructing an engineering and sales office in Los Angeles for occupancy this fall. Located at Santa Monica Boulevard and Harper Avenue, the one-story building will be air conditioned and will have 4,500 sq.ft. of floor space. It will be equipped

How many riveting and welding operations can you eliminate with

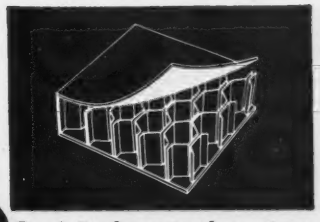
SOLVENT-FREE



Section of Bondolite* floor panel (*T. M. Goodyear Aircraft Corporation) with inserted cargo tie-down ring.



Wing flap section made from Bondolite. Bend is reinforced with Epon Adhesive VI.



Bondolite honeycomb construction. Epon Adhesive VI bonds aluminum skin to central aluminum honeycomb.

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New Epon adhesives are being specified to replace expensive riveting and welding in an ever-increasing variety of aircraft applications. Because they contain no solvents, Epon adhesives permit immediate assembly of metal-to-metal bonded parts. Contact pressure alone is all that is required to form sound bonds. Surfaces before bonding need not be machine-finished and glue lines need not be uniform. Air-relief drilling is never needed.

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The Lockheed F-104A Starfighter, America's fastest combat plane, is now in production for the Air Force. Powered by the G-E J79 turbojet, the fast-climbing, lightweight fighter-bomber flew more than 1,000 m.p.h. in a press demonstration. Its thin, stubby wings, equipped with boundary-layer control, are only 7½ ft. long. The ejection seat shoots downward. Standing beside the plane is Lockheed's Chief Engineering Test Pilot, Herman R. (Fish) Salmon. For security, covers conceal the air scoops.

with the latest testing devices for overhaul and repair of Liquidometer instruments. . . . A miniature magnetic amplifier relay weighing only 6 oz. has been developed for use in guided missiles, air-borne computers, and circuits employing photocells, transistors, or thermistors. Suited for applications requiring a highly sensitive, vibration-resistant relay, the small unit has no magnetic field and requires no shock mounting.

• **Lockheed Aircraft Corporation** plans to start construction soon on a nuclear research and test facility on a large tract near Dawsonville, Ga. The facility will be owned by the Government and operated by Lockheed in connection with the Air Force's nuclear-power-aircraft development program. Although no details were announced, the company said the buildings and equipment at this multimillion-dollar facility will ultimately comprise one of the finest laboratories for aircraft nuclear research in the United States. For safety reasons, the laboratory will be situated in the midst of about 10,000 acres of hilly, heavily wooded land. The laboratory staff will eventually grow to about 500 persons, mostly scientists, engineers, and technicians . . . The Georgia Division plans to spend $7,500,000 on an engineering building and supporting research laboratories. Work will begin late this year on the engineering building, which will have 300,000 sq.ft. and will be air-conditioned. . . . Lockheed will build a two-seat version of the F-104 supersonic jet fighter for the Air Force. Designated the F-104B, it will be capable of flying combat missions, as well as checking out pilots.

• **The Glenn L. Martin Company . . .** The three-stage rocket vehicle for Project VANGUARD, which is being designed and built by Martin, will resemble a giant rifle shell complete with bullet. The first-stage rocket, shaped like the Viking research rocket, will be about 45 ft. long. The third-stage rocket, with the satellite attached to its nose, will be carried completely enclosed within the second-stage rocket. The satellite launching vehicle will be the first liquid-fuel rocket designed to be controlled without the use of fins, a scientific breakthrough by Martin engineers. The vehicle will be kept on its predetermined course by moving the rocket engine (mounted on a gimbal) so that the thrust of the engine will push the entire vehicle in the desired direction. The third-stage rocket, designed to boost the satellite's speed to 18,000 m.p.h. in its horizontal orbit, will use a solid propellant because of its simplicity. Unlike the vehicle, the third-stage rocket carrying the sphere will have no electronic guidance system. It will have a spinning movement to ensure directional stability. The entire flight of 1,500 miles, up to the point at which the satellite will be launched about 300 miles above the earth, will be completed in 10 min. Starting vertically, with the first rocket carrying it to an altitude of 30 to 40 miles, the vehicle will accelerate and then coast in a curving, controlled trajectory until it is flying parallel with the earth's surface. With launching scheduled for early in 1958, Project VANGUARD is under Navy management and involves several subcontractors. (See the March issue of the REVIEW, pp. 55–59.)

• **McDonnell Aircraft Corporation** is developing a supersonic, carrier-based, all-weather attack fighter for the Navy. It will be called the F4H-1. . . . The Navy is conducting evaluation tests of the McDonnell F3H-2M, missile-carrying version of the Demon jet fighter. The F3H-2M, which is in the 600-m.p.h. class, carries a number of missiles stowed under the wings, in addition to rapid-firing high-velocity 20-mm. cannon. It operates from carriers. . . . McDonnell's Industrial Engineering Department has embedded a small radioactive source in the body of each tool that might be left in an airplane or subassembly by a careless worker. Rivet bucking bars and other small tools that have been misplaced will be located by a scintillation counter during a preflight inspection. The amount of radiation is slight—no more than is produced by an instrument panel containing radium dials.

• **Minneapolis-Honeywell Regulator Company . . .** A reference guidance system for the Project VANGUARD satellite will be designed and manufactured by the Aeronautical Division under subcontract from The Glenn L. Martin Company. It will be a self-contained, three-axis guidance system capable of sensing the slightest change from the rocket's desired trajectory. Information necessary to make corrections will be relayed through an autopilot to the servomotors of the VANGUARD vehicle. Corrective movement transmitted by servos to the rocket engine, mounted on a gimbal, will keep the VANGUARD on its course. Changing the direction of the engine thrust will push the entire vehicle in the desired direction. The "brain" of the guidance system will be three HIG (hermetic integrating) gyros to sense roll, pitch, and yaw, combined with other components manufactured by Honeywell. A HIG gyro is so accurate that it can sense movement 3,000 times slower than the movement of an hour hand on a watch. The extremely high speed of the rocket makes it imperative that any deviation from course be measured and corrected instantly.

• **Northrop Aircraft, Inc.,** has begun construction of a $655,000 engineering test building at its plant in Hawthorne, Calif. The two-story structure will contain offices, laboratories, and a high-bay shop area. There will be 48,000 sq.ft. of floor space.

• **Pan American World Airways, Inc. . . .** Pan American anticipates 20 per cent more travel to Europe this summer than last year, when all records for transatlantic air traffic were broken. P.A.A. plans to provide 100,000 seats to Europe during June, July, and August. Seventy-five per cent will be tourist seats. The number of flights between the United States and Europe will be increased from 116 a week to 150. . . . Two new Vice-Presidents of Pan American are Robert B. Murray, Jr., former Under Secretary of Commerce for Transportation, and A. J. Kelly, who has been the company's Regional Director for Western and Central Europe since 1947.

• **Piasecki Aircraft Corporation . . .** Robert G. Kutzer, a founder of this company, has been elected Assistant Treasurer. He was formerly Senior Accountant-Auditor of Vertol Aircraft Corporation. Rudolph Deetjen, a New York investment banker, has been elected a Director.

• **Radioplane Company . . .** A parachute that is expected to permit bail outs at transonic speeds and extremely high altitudes is being developed by Radioplane in conjunction with the Navy's Parachute Test Facility at El Centro, Calif. Called

the Skysail, it is described as a canopy of concentric cloth rings assembled from specially shaped panel sections. The canopy is designed to produce a high degree of stability that is expected to reduce injuries to jumpers when they land. The Skysail utilizes a parachute pack that is designed to be safe against inadvertent opening by air blast when a flier bails out at a speed greater than 450 m.p.h. Its harness design has been made more comfortable by the use of wider webbing bands at high stress points where most of the opening forces are transmitted to the jumper. Greater comfort and safety also result from the fact that the harness is made in custom sizes.

• **Ryan Aeronautical Company** is producing large fuselage sections for the Boeing KC-135 jet tanker-transport and will build similar fuselage sections, 60 ft. long, for the Boeing 707 commercial air liner.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation . . .** Sperry announces the development of an electronic system providing "hands off" automatic, precision control of commercial jet air liners flying between the relatively slow speed of 100 m.p.h. and sonic speeds. The new SP-30 flight control system, the company says, will provide turboprop and turbojet aircraft with levels of air safety and passenger comfort surpassing anything produced by Sperry in 40 years of automatic-pilot development. Among its new features are (1) simplified radio beam-coupling equipment which "ties" the control system to radio station facilities for automatic navigation, with the pilot monitoring flight through Sperry's integrated "pictorial" instruments; (2) inertial path damping, a secret development providing extremely close altitude, cruise, and radio guidance control required for jets; (3) a "practically no-drift" gyro to ensure automatic, pinpoint navigation even in the normally hazardous polar regions; and (4) a special safety monitor which, together with beam-coupling equipment, may contribute heavily toward improving all-weather landing operations by helping to minimize the likelihood of missed approaches. The SP-30 uses transistors and magnetic devices in place of vacuum tubes. A major departure from conventional flight-control systems is the use of acceleration-sensing devices for stabilization control of an extremely sensitive nature. . . . The Navy has announced that Sperry's supersonic air-to-air guided missile, the Sparrow I, is now in use. Pilots have been trained to operate the Chance Vought F7U-3M Cutlass, armed with the Sparrow, from both carrier and shore bases. The accuracy of the Sparrow I, the announcement said, has been demonstrated by hundreds of missile launchings against drones. Intended for use against high-speed jet bombers and fighters, the new air-borne missile accelerates to more than 1,500 m.p.h. within a few seconds after launching. It is 12 ft. long, weighs 300 lbs., and has a solid-propellant rocket motor.

• **United Air Lines, Inc.,** is using a water repellent on the cockpit windshields of all its planes to improve the pilots' vision in rainy weather.

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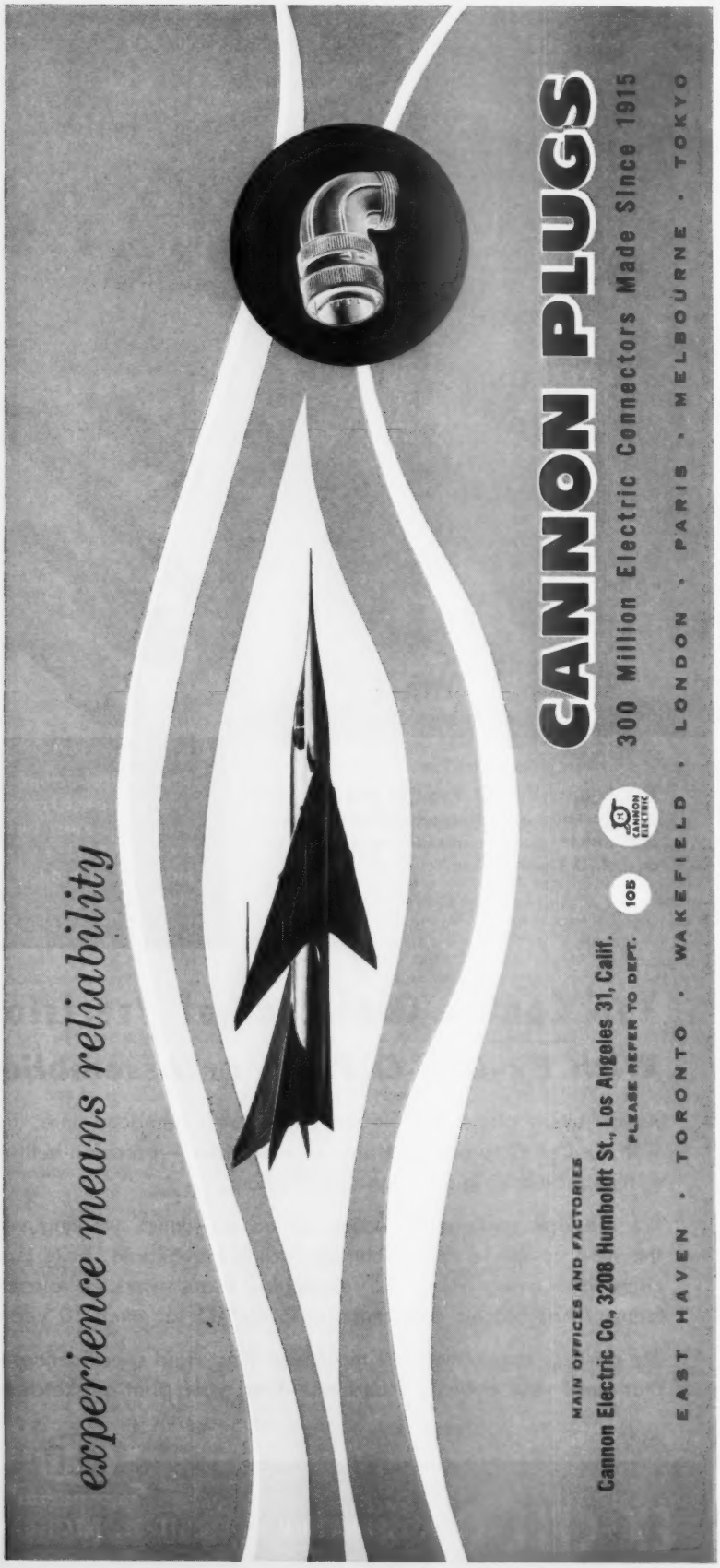
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• **United Aircraft Corporation** . . . Hamilton Standard Division has leased 30,000 sq.ft. of floor space in St. Petersburg, Fla., for a new branch which will engage in product design and development of specialized aircraft equipment. The building, which was formerly used by the U.S. Maritime Service as a training school, is surrounded by water on three sides and adjacent to a small airport. . . . Hamilton Standard also announced it has an engineering team at work on the problem of providing controls for nuclear aircraft engines. The team has a full-time representative assigned to Pratt & Whitney Aircraft's nuclear engine group. . . . Pratt & Whitney Aircraft Division is conducting ten forums at widely scattered points to present the latest service information on P&WA engines to pilots and maintenance men handling private or corporation-owned aircraft. The company has conducted similar all-day sessions, which usually include shop tours, every year since 1948.

• **Vertol Aircraft Corporation** is manufacturing a number of H-21C tandem-rotor helicopters for the French government, with delivery scheduled to begin this month. The H-21 carries 20 passengers or 12 stretcher cases. . . . John M. Schaeffer, President of the Keswick Corporation, has been elected to the Board of Directors.

• **Vickers Incorporated** has opened an application engineering office in the Wyatt Building, Washington, D.C., to provide design, development, and service assistance to users of aircraft oil-hydraulic systems in the Middle Atlantic Coast area. . . . Vickers Electric Division has been selected to design and manufacture the magnetic amplifier autopilot unit that will control the flight of the Project VANGUARD launching vehicle. The autopilot will take its flight instructions from the gyro reference system. It will operate as necessary to keep the three-stage rocket on its predetermined flight course by moving the rocket engine, mounted on a gimbal, so that the thrust of the engine will push the entire vehicle in the desired direction. . . . Vickers has developed a personnel rescue hoist system based on a new "packaged" installation concept. Intended primarily for helicopters, the new 600-lb. capacity hoist is applicable for all air-borne winch installations and can be installed or removed in less than an hour. The packaged design of the hydraulically powered unit provides maximum flexibility in installation and maintenance. . . . Vickers has issued an 8-page brochure describing special and standard hydraulic valves for airborne application.

• **Westinghouse Electric Corporation** . . . The Electronics Division is constructing a multimillion-dollar plant near Friendship International Airport, Baltimore. Scheduled for completion July 1, the plant will provide 210,000 sq.ft. of floor space for the manufacture of radar, fire-control, and missile-guidance systems. Engineering laboratories and administrative offices will occupy an additional 140,000 sq.ft. The electronics plant consists of three buildings and is adjacent to the plant of the Westinghouse Air Arm Division. . . . Westinghouse has developed a compact, tubular heater to solve an icing problem in

the tail-surface control system of the Boeing B-52. The electric heater, rated at 193 watts, keeps the temperature of a hydraulic actuator above freezing. . . . The Aircraft Equipment Department, Lima, Ohio, announces a new line of continuous-duty, explosionproof aircraft motors (Type AK) for coolant pumps. They are available in ratings from 1/100 to 1/7 hp. within the speed range of 2,800 to 14,000 r.p.m.

IAS SECTIONS

Meet Your Section Chairman

W. Donald Dodd, Jr.

Dayton Section

Following a youthful aviation hobby to the end of the rainbow, Walter Donald Dodd, Jr., is now employed by the Air Force as a civilian engineer engaged in research and development. A model-plane contest winner with 20 prizes to his credit, he began building model planes at the age of 13 in St. Louis and climaxed his achievements in this line by capturing first prize in the Mississippi Valley Sweepstakes in 1940.

Don is Assistant Chief of the F-89 Weapon System Project Office in the Fighter Aircraft Division, Systems Management Directorate, Headquarters, Air Research and Development Command, Detachment No. 1, Wright-Patterson AFB. During World War II and the Korean War, he served 6 years as a research and development engineering officer of the Air Force at Wright-Patterson. He received his Air Force commission from the ROTC when he graduated from college in 1942.

Don's first business positions in St. Louis were as a laboratory assistant at his *alma mater*, Washington University, and as an inspector of mechanical equipment in the U.S. Engineers Department, St. Louis District. After receiving a B.S. in Mechanical Engineering in 1942, he did graduate work at the Wright-Patterson Graduate Center of Ohio State University while he was a civilian. He received the professional degree of Mechanical Engineer from Washington University in 1950.

For 2 years Don served as a Project Officer in the Equipment Laboratory; then for 2 years he was a Model Test Engineer in the Power Plant Lab. Next came a promotion to Chief of the NACA Power Plant Unit and then to Chief of the Propulsion Systems Branch of the Engineering Division Staff. Don later became Chief of the Basic Research Liaison Office, Power Plant Laboratory, and subsequently served as Project Engineer on several jet-engine developments before transferring to the New Developments Office of the Fighter Aircraft Division.

A registered professional engineer in the State of Ohio, Don has been an active member of the Institute for 8 years, serving on the Dayton Section Council and as Program Chairman, Treasurer, Secretary, and Vice-Chairman of the Dayton Section. Don and his wife, Ada Kay, are proud of their 2-year-old son, Kevin Whitcomb Dodd.

Chicago Section

A joint meeting of the Chicago Sections of the IAS and the American Rocket Society was held February 22 at Illinois Institute of Technology. About 50 members and guests had dinner in the Student Union Building, and 68 attended the meeting.

The speaker was John Stungis, Jr., of the Columbus (Ohio) Division of North American Aviation, Inc. He spoke on "Aspects of Power Plant Installation Testing."

Stressing that the power plant is the heart of the airplane, Mr. Stungis said it is the responsibility of the power-plant engineer to install engine and supply services in such a way that operation will be satisfactory within limits throughout the operational envelope of the airplane. The basic problems of mating engine to aircraft, he said, are ducting, cooling, control compatibility, fuel system compatibility, and starting.

In attacking these problems, an analytical approach is desired, but much qualitative testing usually is required. Mr. Stungis indicated that, basically, three stages are followed in any solution. They are development, ground testing, and flight testing.

In the development stage, a number of test tools are used. These may be any or all of the following: fuel lab, oil lab, engine test stand, and research lab. Under research lab are grouped such varied support functions as environmental testing, structural testing, wind-tunnel testing, and analog computer. Throughout his presentation, the speaker pointed out the problems and the importance of power-plant installation testing.

HARRY W. WIANT, *Secretary*

Dayton Section

On March 15, forty-five members and guests of the Dayton Section heard a talk by David S. Gabriel of the Lewis Flight Propulsion Laboratory of NACA on installation problems in high-speed turbojets. Mr. Gabriel categorized these problems into four areas: inlet-air matching, thrust reversal, exhaust, and controls. Curves showed the losses that can be encountered with a typical subsonic inlet when operating up to Mach 2.5. The thrust loss at Mach 2.5 can be 30 to 40 per cent. On the other hand, an inlet design for the high-speed condition can result in a 50 per cent thrust loss in transonic speed. Examples of variable inlets were given. High-speed movies were shown of diffuser oscillation resulting from the normal shock of the diffuser popping in and out of an unmatched inlet.

Similarly, a fixed-exhaust nozzle can result in a 50 per cent thrust loss at Mach 2.5. Examples of variable-nozzle configurations including the mechanical, ejector, and plug nozzles were given. A movie of an air-cooled plug in operation was shown, and there was a discussion of external-flow effects which can cause flow separation with attendant losses. Schematics were shown displaying the six control variables for variable geometry with examples of the function of each.

On the subject of thrust reversal, Mr. Gabriel showed that, with 80 per cent thrust reversal, it was possible to reduce the landing roll to 30 per cent. Modern and future high-speed turbojet aircraft will have very high wing loadings, and this usually means long landing rolls. Hence, it is felt that thrust reversal is going to remain with us. There were slides of examples of some established thrust reversal configurations and movies of an experimental installation.

T. J. KEATING, *Secretary*

Hagerstown Section

Marion Maxfield, Assistant Director of Customer Relations, Fairchild Aircraft Division, addressed 64 members and guests at the March 13 meeting. He spoke on the Fokker F-27 Friend-

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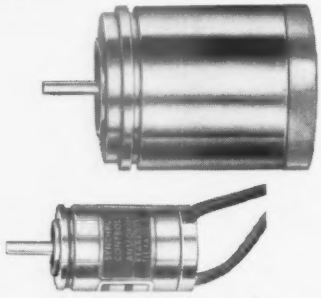

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ship transport which Fairchild plans to manufacture as a replacement for the DC-3. The F-27, he said, meets the demand for a more efficient, modern airplane with higher pay load for short-haul operation.

Mr. Maxfield's talk was supported by a film and slides depicting manufacturing processes and performance data.

C. L. CHUMLEY
Secretary-Treasurer

Indianapolis Section

The Indianapolis Section met March 12 at Purdue University, with the Student Branch handling the meeting details under direction of its Chairman, Lewis Rittenhouse. The attendance exceeded 100.

A tour of the Purdue Rocket Laboratories on the west side of Purdue Airport preceded the dinner meeting. The tour was attended by 80 engineers who had traveled some 60 miles from the Indianapolis area. Small groups were conducted through the facility by the laboratory staff and graduate students. The program closed with a 20-min. color movie showing the firing of several rocket motors at this facility. Cecil Warner supplemented the film with a lecture on the history and operation of the Purdue Rocket Laboratories.

After dinner at the Purdue Memorial Union, Paul Welles, visiting from the IAS New York office, presented the award for the winning paper in the Student Paper Competition conducted by the Indianapolis Section. The winner was Franklin Chen Yueh Kun, a senior at Purdue in the Aeronautical Engineering School. His paper was entitled "Airfoil Blades Rotating on a Cylindrical Locus and Application to a Wingless-Tailless-VTOL Airplane." The judges were Dimitrius Gerdan, Harold M. DeGroff, and J. E. Goldberg. A certificate and check were presented to Mr. Chen by Mr. Welles. D. L. Clingman, a junior in Purdue's School of Aeronautical Engineering, won honorable mention for his paper on "Practical Thrust Reversal."

The quality of the papers presented was gratifying, and a highly competitive contest is anticipated next year. Planning for the Second Annual Indianapolis Conference to be held in the spring of 1957 is already under way.

The speaker of the evening was the Section Vice-Chairman, M. J. Zucrow, Professor of Gas Turbines and Jet Propulsion at Purdue. His topic was "The Turbojet Engine—Its Problems as a Propulsion Engine for Supersonic Flight." Graphs and charts were presented to show in orderly progression the changes and design difficulties that will be encountered for compressors, burners, turbines, and afterburners as

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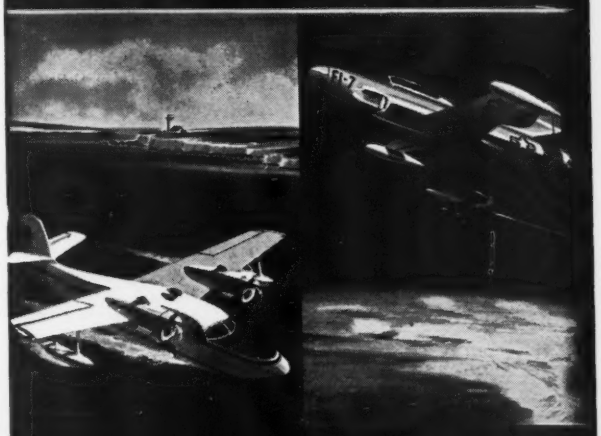

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aircraft speed increases above Mach 2.0. Cooling probably will be accomplished by using the fuel as a heat sink.

Dr. Zucrow concluded his presentation with sketches of several composite engines for high speeds in which the turbojet portion of the engine is used up to a speed at which the ramjets take over and the turbojet is shut down.

During the business meeting, H. E. Helms was appointed Publicity Director for the Section. Paul F. Ferreira, Jr., Chairman of the Nominating Committee, announced the nominations for next year's officers. The election will take place April 16. A new committee called the Information and Education Committee was appointed, with R. L. Myers as Chairman and William R. Haney, Jr., John Duff, Roger Fleming, and John Bollard as members. Their job is to investigate ways and means of getting information about aeronautical and related engineering vocations to students at the high school level.

Allen Stokke, Program Chairman for the Section's final meeting of the season and banquet, announced that the event will be held April 16 at the Marrott Hotel. The speaker and guest of honor will be Brig. Gen. Marvin C. Demler, USAF, of the Air Research and Development Command. His subject will be "Air Force Aims in Aeronautical Development."

P. N. BRIGHT, *Chairman*

The Area Rule

Los Angeles Section

Richard T. Whitcomb, MIAS, Assistant Head of the 8-Foot Transonic Wind Tunnel at Langley Aeronautical Laboratory, NACA, presented a paper on the "Zero-Lift-Drag Characteristics of Wing-Body Combinations at Transonic Speeds" at the dinner meeting on February 16. Dr. Allen Puckett of Hughes Aircraft Company acted as Guest Chairman. Prepared comments on Mr. Whitcomb's paper were offered by D. H. Bennett of Convair-San Diego, K. F. Van Every of Douglas-El Segundo, and Jim Hong of Lockheed-Burbank.

Mr. Whitcomb's paper was concerned with the physical basis and practical application of the "area rule." He said considerations of the flow at transonic speeds lead to the conclusion that the drag rise of a wing-body combination is primarily dependent on the axial distribution of the total cross-sectional area. By wrapping the cross-sectional area of the wing around the body, an equivalent body of revolution can be generated which will have a drag rise similar to that of the wing-body combination, as was shown by slides and schlieren pictures. The schlieren pictures showed that, at some distance away from the body, the shock pattern of the wing-body combination and the equivalent body are similar.

From the foregoing it may be concluded that a minimum drag rise would be obtained by designing a wing-body combination with an area distribution similar to that for a smooth body. The results obtained experimentally indicated this to be true at transonic speeds. At higher speeds, the drag of the indented wing-body combination approaches the drag of the original wing-body combination.

Difficulty in achieving the desired results was encountered for straight- and delta-wing configurations, probably because of the poor local geometry on the body due to the rapid changes in wing cross-sectional area for these configurations.

The effect of external nacelles on the transonic drag rise may also be interpreted on a basis of the area-rule concept. This was illustrated by a series of tests on a wing-body combination with symmetrically mounted nacelles located at various wing stations on a 45° swept wing. The highest transonic drag was obtained when the nacelle position caused their frontal area to add to the largest wing-body frontal area, and the

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drag was progressively reduced when the nacelles were moved away from this point.

Mr. Whitcomb concluded that the results presented have shown that near the speed of sound the drag rise for a low-aspect-ratio wing-body combination is generally a function of the actual distribution of the cross-sectional area and that reshaping the fuselage to minimize and smooth out the cross-sectional area distribution resulted in drag reductions at transonic and moderate supersonic speeds.

Mr. Bennett, in his comments, pointed out that, in addition to the performance gains attainable from the use of the area rule, other beneficial effects found were the reduction in transonic buffet and minimization of unpredicted trim changes.

Mr. Van Every observed that the importance of the area-rule principle cannot be overrated and that its greatest usefulness arises from the simplicity of the concept and its application. Apart from its value as a design tool for obtaining an optimum arrangement of airplane components, the area rule concept also makes it possible to calculate the wave drag for complex configurations at sonic and supersonic speeds. The equivalent-body model offers a simple and cheap method of obtaining first-order experimental data on wave drag at transonic speeds. It may be used to find or cure critical areas where buffeting may occur.

Poor results may be obtained from the area-rule concept if its application results in component parts with regions of sharp curvature which can give rise to high local velocities. He concluded that in practical use the results may not always prove as rewarding as the theory would imply and that its usefulness depends primarily upon the skill with which it is used.

Mr. Hong, in his comments, noted that the area rule is not a cure-all for transonic ills. In some configurations, subsonic drag is substantially increased by the use of the area rule, and, although wave drag is decreased, the total airplane drag may actually be higher.

Because of deleterious effects at supersonic speeds, the use of the area rule may actually decrease airplane performance.

The increased subsonic drag, which penalizes range and subsonic ceiling, combined with the more complex structure requiring curved longerons and increased weight will, in many cases, reduce the total airplane capability.

The use of a thin-straight-wing configuration, whose total wing cross-sectional area can be considerably less than an equivalent-weight swept wing,

obviates the necessity for a bumped-in fuselage.

DICK FULLER, *Secretary*

▶ The Specialist Meeting on March 13 featured a talk on "Electron Distribution in a Strong Shock Front" by John W. Bond, Jr., of the General Electric Company, Schenectady, N.Y.

The propagation of a highly ionized shock front through the gases air and argon was described. Various physical effects due to the presence of ions in the shock front were considered, and, in particular, the accompanying positive electric potential was analyzed. In addition, various experiments and applications were discussed.

E. R. VAN DRIEST
Meeting Coordinator

▶ On February 7, Norman J. Ryker, Senior Structures Engineer of the Missile Development Engineering Division of North American Aviation, Inc., discussed the "Stability of Orthotropic Shells Under Radial Pressure and Axial Loads" at a Specialist Meeting. He stated the problem and set up the differential equations necessary for orthotropic cylinders, and he presented results in the form of curves for the critical axial loads on complete cylinders of orthotropic materials. It was seen that the results were quite different from those obtained with isotropic cylinders.

L. A. RIEDINGER
Specialist Meeting Coordinator

San Diego Section

Beginning this month, we will include summaries of some of the more interesting activities of our committees with the meeting reports submitted for publication in the AERONAUTICAL ENGINEERING REVIEW. We believe the members of other Sections may take an interest in this more general type of news that is not usually covered in the accounts of meetings and talks.

Section Meeting

"Soaring Flight" was the subject of a paper presented at the technical meeting on March 13 by William S. Ivans, Jr., Chief Electronics Engineer, Convair, A Division of General Dynamics Corporation. Mr. Ivans, holder of the single-place glider world altitude record of 42,100 ft., was named to the four-man team which will represent the United States in the biennial world-wide glider competition in France this summer. Guests at the meeting were Chase Allen, of the San Diego State College Student Branch, and members of the San Diego Glider Club and Air Explorers Squadron No. 340, Boy Scouts of America, which is sponsored by the San Diego Section.

Committee Activities

The Student Aid Committee, of which Jim Bowyer is Chairman, has expanded its activities considerably during the past year. In addition to providing support for the Student Branch at San Diego State College and sponsoring the Air Explorers Squadron, the activities include participation in two of the annual functions sponsored by the San Diego city and county schools.

One of these functions is the Science Fair. The Fair provides public school students with the opportunity and encouragement to exhibit their own projects. Awards are made for the best projects exhibited in each of several categories, and the best of these are granted general awards.

The San Diego Section participates in this Fair by providing a technical exhibit, by displaying the activities of the Section-sponsored Air Explorers Scout Squadron (thus encouraging high school students to join in these activities), and by providing a counseling service to those students who are interested in engineering as a career. Appropriate literature from the Engineering Council for Professional Development and from the IAS and other pertinent data are made available to the students seeking counseling.

The second of these functions is a series of live television programs produced by the Audio-Visual Aid Section of the San Diego County School System for viewing by fifth- and sixth-grade students. Several of the programs of this general science series are devoted to aeronautics, and the San Diego Section has furnished technical advice, panel personnel, and training aids for these programs:

(1) The first aeronautical program is devoted to the discussion and illustration of the scientific principles involved in the flight of heavier-than-air, fixed-wing aircraft.

(2) The second is devoted to a discussion of the technological aspects of flight—that is, the practical application of scientific principles to the attainment of thrust and lift and to the minimization of drag and structural weight.

(3) The third program is devoted to flight test and has, in the past, included some short movies.

The panels include two or three technically qualified members from the San Diego Section and two students selected from the public school system. The students on the panel ask questions based on the presentations made by the Institute members.

The Historical and Museum Committee under Chairman Fred Landgraf has been busy delving into San Diego contributions to the early development of aviation. Plans are being made to decorate the foyer of the San Diego IAS Building with a large photo mural depicting significant events in aviation history which took place in this area. The Montgomery glider flights, the early Glenn Curtiss work with water-based aircraft, the first refueling in air, the first intercity air line, and the design and building of Lindbergh's "Spirit of St. Louis" are a few of the events which will be pictured. It is hoped that sufficient enthusiasm may be generated to make possible the fabrication of a large-scale model of the original Montgomery glider for display in the IAS Building.

R. A. FUHRMAN
Corresponding Secretary

Lockheed Electra

San Francisco Section

Ten wives attended the dinner meeting on March 22 and heard a discussion of the Lockheed Electra turboprop transport by R. Richard Heppe, Head of the Aerodynamics Department of Lockheed Aircraft Corporation.

Chairman George Cooper called upon Russell G. Robinson, Assistant Director of Ames Aeronautical Laboratory, NACA, to present a plaque to David L. Cochran. Mr. Cochran won the national first prize in the graduate division of the 1955 Student Paper Competitions conducted by IAS under auspices of the Minta Martin Aeronautical Student Fund. Preparing for a Doctor's degree in Mechanical Engineering at Stanford University, Mr. Cochran wrote his winning paper on "A Simple Means for Producing Efficient Wide-Angle Diffusers."

Speaking on the Electra, Mr. Heppe, who is a past Chairman of the Los Angeles Section, pointed out that one of the principal design criteria for the airplane was that of take-off and landing performance. He presented statistics on approximately 1,200 airports of the world, showing that only half of them have runways over 5,000 ft. long. Only 30 per cent have runways longer than 6,000 ft.

Because the Electra transport was designed principally for short-range operation, it had to have landing and take-off characteristics that would permit using most of these airports throughout the world. Therefore, it was designed with take-off and landing characteristics that will permit it to use 5,000-ft. runways in short-range operation. When longer range is desired, the plane will require about 6,000 ft. The longer runways are usually available

Russell G. Robinson, FIAS *(left)*, presents the first Minta Martin Award for a paper by a graduate student to David L. Cochran at a meeting of the San Francisco Section.

at airports from which long-range operations would be carried out.

Mr. Heppe also offered statistics forecasting the growth of air travel in the United States. According to these estimates, there will be 20 billion passenger miles flown this year. By 1965, passenger traffic is expected to double.

Because about 60 per cent of all flights of major carriers in the United States are under 200 miles, the speaker said, the need for a good, short-range transport is apparent. It is Lockheed's belief that the Electra will fulfill all requirements for good, economical, short-range operation.

The Electra is based on a great deal of background information gained from Lockheed's experience with the YC-130 and the turboprop Constellation developments. Mr. Heppe discussed the operating characteristics designed for the Electra and pointed out that the maximum speed of the aircraft will grow to about 470 m.p.h. as larger turboprop engines become available commercially.

He pointed out several features of the plane that should appeal to passengers, such as two entrances with integral staircases, wider seats than are presently available in first-class aircraft, and the fact that this will be the first four-engined transport to permit carry-on baggage. The meeting adjourned after a lively discussion.

J. A. BERT, *Secretary*

Seattle Section

Holden W. Withington, a Senior Project Engineer in the Seattle Division of Boeing Airplane Company, spoke at a dinner meeting held on March 14. His subject was "Silencing the Jet Aircraft."

Mr. Withington said his lecture was actually a progress report. He told of several nozzle configurations which were tested in the wind tunnel and at full scale, in flight. The results of these tests were shown on slides. The 12-lobe configuration gave the greatest reduction in noise level. At first, the nozzle pressure ratio was poor. Steps were taken to improve the aerodynamic cleanness inside the engine, resulting in more efficiency.

Actual in-flight recordings of the standard and improved nozzles gave the audience an opportunity to hear the difference themselves. This noise reduction occurs because the low frequencies are eliminated. The noise is reduced just as much at low power as at high power. But at low power the compressor noise is so high that the reduction is hardly noticeable. Taxi tests were run using the standard and improved nozzles. The object was to determine at what degree from the plane's axis a spectator hears the maximum noise. The improved design has a peak about 10 deg. later than that for the standard. Again recordings were played for the audience.

The improved nozzle means a sacrifice in weight and performance but a gain in the amount of aft-cabin soundproofing. The weight of the trailing-edge structure is also reduced by this nozzle configuration.

ELAINE GETHING
Secretary

Texas Section

At a confidential meeting March 7, the Texas Section heard a talk on "Air-Frame and Propulsion System Matching for Supersonic Bomber Aircraft" by Edmund B. Maske, AFIAS, Chief of Aerodynamics, Convair-Fort Worth.

Mr. Maske demonstrated a method of determining engine size and type for supersonic bomber aircraft. He pointed out the significance of mission profile and expected growth trends to the final engine selection.

The technique shown was a generalized one considering afterburning and nonafterburning turbojets. No specific aircraft were discussed.

▶ Seventy members and wives attended a dinner meeting March 2 at Amon Carter Airport.

The speaker, S. O. Perry, Assistant Chief Engineer, Chance Vought Aircraft, was introduced by C. O. Miller, Program Chairman. Mr. Perry's subject was "The Missile Grows Up." Mr. Perry has been directly connected with the Regulus project at Chance Vought since its beginning. His talk was supplemented with movies and slides of Regulus operations.

Mr. Perry pointed out that the main problem in producing missiles is to bring together proved details, methods, and equipment to produce an overall workable system. Another equally important part of missile manufacturing is the quality control required. A malfunction that might be a nuisance in a

Howard F. Marx, MIAS, of Temco Aircraft Corp., is honored by the Texas Section for "outstanding service." I. Nevin Palley, AFIAS *(right)*, a member of the IAS Council, is presenting him a key. Watching the presentation are Chairman John H. Boucher, MIAS *(left)*, and Jack Frye, FIAS, guest speaker at the meeting.

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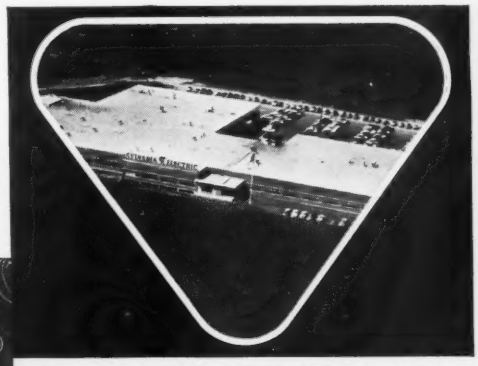
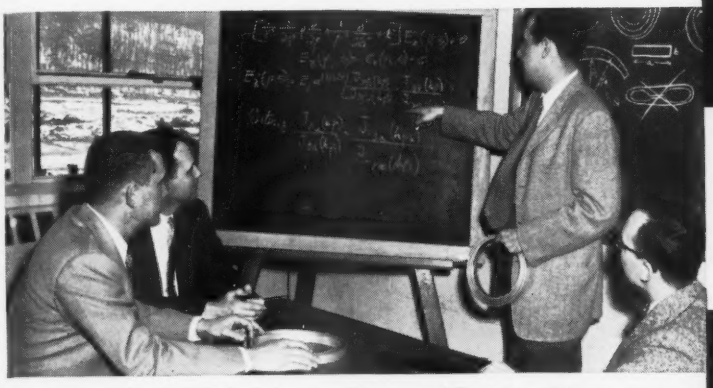


New Sylvania Waltham Laboratories, devoted to advanced projects related to guided missiles and aviation electronics. The air-conditioned building has 120,000 square feet of floor space.

Environmental testing of unique equipment—a radome designed as an integral part of a high-performance airplane wing. Left to right: Dr. Frank Rosato, Frank Lambert, John Ricketts and Joseph Shagoury of the Waltham Laboratories.



Sylvania Avionics Laboratory Manager and Department Managers discuss a problem in delay circuiting employing coiled wave guide. Left to right: John Jewett, Laboratory Manager Richard Osgood, Dr. Carl Faflick, and Fred Anderson.

Radome

for airplane wing edge

. . . a challenging problem in Avionics

ENGINEERING a radome for the edge of an airplane's wing demands skill and experience in both aerodynamics and electronics. Sylvania's Avionics Laboratory provided these qualities to meet this unique problem in developing an advanced electronic system for a high-performance military aircraft.

Highly advanced electronics projects of many kinds for many environments . . . land and sea, as well as air . . . are constantly being carried out by engineers of the Avionics Laboratory. They have made notable achievements in computers, radar, warning devices, detection devices, jamming equipment, countermeasures, and counter-countermeasures.

In addition to the Avionics Laboratory, Sylvania's Waltham, Mass., facilities include the Missile Systems Laboratory and the Applied Research Laboratory. Each of the three is engaged in pushing back scientific frontiers in electronics—each is a vital part of Sylvania's Electronic Systems Division.

In all of Sylvania's Electronic Systems Division installations, the *right* people work with the *right* facilities, within a sound managerial environment. That is why they have produced *right* solutions to a variety of problems, and have made many important contributions in the fields of aviation electronics, guided missiles, countermeasures, communications, radar, computers, and control systems. Whether the problem is military or industrial, Sylvania's business is to come up with solutions that are *producible*.

The Electronic Systems Division has plant and laboratory facilities at Buffalo, N. Y., and Mountain View, Calif., in addition to its Waltham activities. All are staffed with top-ranking scientists and engineers, backed with Sylvania's extensive resources in the electronics field.

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piloted aircraft could be fatal to a missile.

▶ The Texas Section held a dinner meeting at Amon Carter Airport on February 24 with 200 in attendance. The purpose of the meeting was to extend a formal welcome to the Frye Corporation, the newest member of the aeronautical fraternity in the Dallas-Fort Worth area.

Prior to the main speech, the Vice-President—Engineering of Temco Aircraft Corporation, I. Nevin Palley, a member of the National Council of the IAS, presented a key to Howard Marx of Temco in recognition of his outstanding service to the Texas Section.

Jack Frye, President of The Frye Corporation, which was organized in 1954, was the principal speaker of the evening. He gave an interesting account of the reasons he is developing the F-1 transport. Mr. Frye's extensive background in transport aviation, culminating in the presidency of TWA, has given him an excellent opportunity to determine what the requirements should be for the so-called "DC-3 replacement transport." He sees a great opportunity for his airplane not only in the United States but also in foreign countries, where in many instances air transportation is a necessity rather than a luxury. Present-day transport airplanes keep getting further away from the needs of many foreign countries.

The Frye airplane is being designed with the idea of making it simple, dependable, economical, capable of operating from small fields under primitive conditions, and capable of being maintained by personnel with minimum skills. It will carry either cargo or passengers or a mixture of both and will be provided with good loading features. It will use well-known, proved materials and well-proved construction methods. It will have a light wing loading and be easy to fly. It will have four engines, with the nacelles designed in such a way that any one of four different engines may be used. Much emphasis will be placed on keeping operating costs down to a minimum. The airplane is to be built by a manufacturer yet to be selected. It is planned also to build the airplane in Europe. The entire project is being financed by private capital.

CURTIS L. TURNER, JR., *Secretary*

STUDENT BRANCHES

Agricultural and Mechanical College of Texas

An NACA movie entitled *High-Speed Flight Research* (*Muroc*) was shown for 25 members at the March 6 meeting.

Explaining the purpose of transonic and supersonic research flights conducted over the Southern California desert, the film pointed out that airborne instrumentation plays a vital part in recording data obtained during the flights. The plane is tracked by electronic devices on the ground and is loaded with automatic test equipment that permits velocities, accelerations, loads, and other continuously changing information to be telemetered to the ground receiving station. In addition, the pilot's comments during the flight are tape-recorded on the ground. If the plane should meet with an accident, most of the test data accumulated during the flight would not be lost.

Six research planes shown and described in the NACA film were the Bell X-1 and X-5, the Northrop X-4, the Convair XF-92A, and the Douglas D-558-I and D-558-II.

HARLESS R. BENTHUL
Secretary

Brown University

Plans for the Northeastern Regional Student Conference to be held here April 20 and 21 were made at the Student Branch meeting on April 11. The visitors will be shown the Transonic Wind Tunnel and the Aerodynamics Laboratory. Before they arrive, a similar tour will be conducted for the Brown Student Branch.

A movie made in the Aerodynamics Laboratory, some portions of which have been televised, was shown at the end of the meeting. It showed the physical equipment and operation of the wind tunnel and the formation of shock waves around a test model (the F-86) which had been remodeled to conform with the "area rule" discovered by NACA.

DAVID B. PETERSON, *Secretary*

California State Polytechnic College

Gordon L. Getline of Convair's San Diego Division spoke on "The Noise Factor in Aircraft" at the March 1 meeting. He discussed the two major types of noise: aerodynamically generated noise caused by pressure variations in the fuselage boundary layer and noise caused by the engines.

The speaker also presented a movie, *The First Transitional Flight of Convair's XFY-1*, which showed the "Pogo" take off vertically and change to horizontal flight. Landing maneuvers were shown too.

ELMER J. BISHOP, *Reporter*

Illinois Institute of Technology, University of Illinois (Chicago), and The Aeronautical University

A joint meeting of the Student Branches of the IAS was held on March 7 at Illinois Institute of Technology.

This meeting, although sponsored by the Chicago Section, was a student affair. The meeting was planned, arranged, and conducted by the students of the three universities in the Chicago area having student branches. On this night the student members played host to the professional members. Thus the meeting provided the students with the opportunity to thank personally the Chicago Section for help and encouragement given throughout the year. It also provided an opportunity for the students from the different Chicago branches to become acquainted with one another while putting together a technical meeting.

The theme of the meeting was "Space Flight." Committee members from the three branches reached an early decision regarding this theme in view of the importance of, and local interest in, the forthcoming International Geophysical Year.

It was decided that two speakers would be needed to cover the subject adequately—one to speak on the unsolved problems of space flight, the other to discuss the earth satellite program in terms of the information we hope to obtain from it, which will aid in the solution of space-flight problems.

John Everett, Honorary Student Chairman of the Illinois Tech Branch, acted as chairman of the meeting while Gene Salerno, Chairman of the Aeronautical University Branch, and Harold Marthinson, Chairman of the University of Illinois in Chicago Branch, introduced the two speakers.

The first speaker was Darrell C. Romick, an aerophysicist engaged in guided-missile engineering at Goodyear Aircraft Corporation. His talk was illustrated by 40 color slides and painted a comprehensive and authentic picture of the development of space flight. The objectives and values of space flight to mankind were outlined, and the status of progress toward its achievement was presented.

The second speaker was John P. Hagen, who is in technical charge of Operation VANGUARD, the earth satellite program, with headquarters at the Naval Research Laboratory in Washington, D.C.

The earth satellite program, a joint effort of The National Academy of Sciences and the Department of Defense, has as its objective the establishment of a satellite in an orbit about the earth and the use of the satellite to perform scientific experiments. Previous experience in experiments conducted beyond the confines of our atmosphere has been limited to the short periods of time made available by rocket techniques. The earth satellite vehicle will make possible long-term observations of quantities observed now only by rockets.

In his lecture, augmented by color slides, Dr. Hagen presented a description of the rocket vehicle and explained the method of launching the satellite into its orbit.

The meeting was attended by 200 students and IAS members from the Chicago area. It was preceded by a dinner for 85 persons at the Commons Building of Illinois Tech.

LT. H. B. LOHEED, USN
Faculty Adviser, Illinois Tech

Indiana Technical College

Forty members were present at the meetings on March 13 and March 27. Plans were made to visit the Chicago Museum of Science and Industry and possibly Midway Airport on April 13.

At the second meeting B. L. Dow, Faculty Adviser, spoke on "Graduation—What Next?"

Roy Krava was appointed to arouse student interest in the speech and scholastic awards offered annually by the IAS.

WAYNE C. BOHANNON, *Secretary*

Institute of Technology, USAF

About 200 students and faculty members attended the March 30 meeting. Two classified films were shown. One dealt with convertiplanes; the other was a guided-missile progress report for 1955.

LT. DOUGLAS S. EGAN, JR.
Secretary-Treasurer

Iowa State College

Ernest W. Anderson, Head of the Aeronautical Engineering Department and Faculty Adviser of the Student Branch, spoke at the March 7 meeting. He reported on the IAS Annual Meeting in New York which he attended, passing on information of interest to the students. Dr. Anderson also reviewed achievements of the Student

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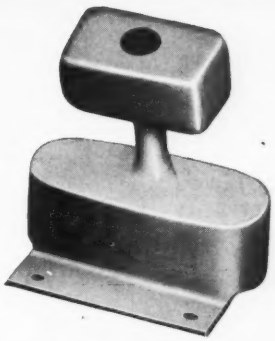

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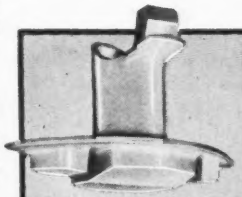

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"PIONEERS IN INVESTMENT CASTING"

Branch and the Aeronautical Engineering Department during the past year.

The following new officers were elected: Harold Ream, Chairman; Carl Vollersen, Vice-Chairman and Senior Representative to the Engineering Council; Marvin Baxendale, Secretary; and Jeff Thompson, Treasurer.

Bob Belt was named Program Chairman and Larry Smith, Junior Representative to the Engineering Council.

ROBERT D. DIGHTON, *Secretary*

Too Heavy!

Mississippi State College

"It's Too Damn Heavy!" was the subject of a talk by Gale Winnet of the Weights Group of the Columbus Division, North American Aviation, Inc., at the March 8 meeting.

Mr. Winnet explained the function of the Weights Group in the design and development of modern high-performance aircraft. Summarizing, he said, "the Weights Group integrates various engineering and production groups."

The work done by a Weights Group consists essentially of two parts—a preliminary weight estimation and a later continuous, detailed weight calculation. Mr. Winnet pointed out that books were kept on the weights of all parts; however, the use of IBM machines has simplified this job somewhat. Calculation of moments of inertia and balance of control surfaces are also functions of the Weights Group at North American's Columbus Division.

Mr. Winnet explained some of the structural problems related to the Weights Group in the design of naval aircraft. The structure in the vicinity of the pilot must be designed for 40 *g*'s, and additional strength is needed to withstand the shocks transmitted from the tailhook.

Combatting aeroelastic effect is another function of the Weights Group. The solution involves placing or distributing weight throughout the wing to counteract the vibration or flutter set up by the aeroelastic effect.

Mr. Winnet said that Weights Groups in the aircraft industry have been in existence only about 15 years. Weights Groups came into existence with the need for higher performance aircraft; this need is still growing, and, consequently, the importance of the Weights Group is growing too.

It was announced that a paper by J. H. Love was to be presented in the IAS Student Conference in Dallas, Tex., and that papers by Charles Dixon, I. Man Moon, and Loutf Hawwa were to be presented at the IAS Student Conference in Atlanta, Ga.

J. H. LOVE, *Secretary*

New York University

A two-part film was shown March 1, entitled *Guided Missiles—Introduction to and Theory of Operation.* Plans were discussed for a proposed IAS reference library on the campus, an "IAS Night" at which awards will be presented, and a trip to the Naval Air Turbine Testing Station at Trenton, N.J. A lecture contest will be held this spring.

ALFRED KUHN, *Recorder*

North Carolina State College

Chairman Dave Gurley was chosen at the March meeting to head a delegation to the Southeastern Student Conference of the IAS. During their stay in Atlanta, the students will tour Lockheed's plant in Marietta, Ga.

A 7-ft. scale model of the B-36 bomber is being constructed for exhibition at the Engineer's Fair April 20 and 21. Members of the IAS Student Branch and other campus organizations are inviting high school seniors throughout the state to attend the Engineer's Fair. In most cases, IAS members are personally contacting seniors in their own high schools.

After the business meeting, Keith Bowman showed slides of photos he had made at the 1955 National Air Show in Philadelphia.

KEITH E. VERBLE, *Secretary*

Oklahoma Agricultural and Mechanical College

R. B. Deal, Jr., Associate Professor of Mathematics, spoke on "The Use of Mathematics in Aeronautical Engineering" at the March meeting.

Practical differential equations, he said, is a major subject in aerodynamics, but the currently important study of compressible flow in the transonic and supersonic ranges is reviving mathematical interest in hyperbolic equations, particularly of the nonlinear type. In designing guided missiles, he pointed out, probability is an important subject.

Professor Deal emphasized that, in looking toward the future, an engineer should endeavor to learn and use available modern knowledge.

Presiding at this meeting were the new officers for the spring semester: Charles Carter, Chairman; Louis W. Powers, Vice-Chairman; and Lyle Becknell, Secretary-Treasurer.

PATRICK Z. WYERS
Assistant to the Secretary

Parks College of Aeronautical Technology

Twenty members present at the April 5 meeting discussed the display for the coming Open House. It was suggested that the Low-Speed Wind Tunnel be run up and a model tested for the spectators.

George Graff, Chief Aerodynamicist of McDonnell Aircraft Corporation, will speak at the April 26 meeting.

GERALD J. PANEK, *Secretary*

The Pennsylvania State University

Fifty engineering students attended the Student Branch meeting on March 14. Chairman James Tedeschi introduced the speaker, Spence Thomason of North American Aviation, Inc., Columbus, Ohio.

Mr. Thomason described the departmental organization and development work at the Columbus plant. His specialty is the Structures Test Laboratory. He presented a film showing drop tests of the FJ-4 Fury jet fighter. Close-ups showed the reaction of the wheels and landing gear as the plane hit the pavement. A humorous film, *Testing the Fury*, was also shown.

JOEL PETERSON, *Secretary*

Polytechnic Institute of Brooklyn

On February 21, Alan Pope, head of the Experimental Division of the Sandia Corporation, delivered a talk entitled "High-Speed Wind-Tunnel Testing." The talk dealt mainly with the problems of near-sonic and transonic testing.

The two chief problems in near-sonic or transonic testing are "choking" and wave reflection. Choking is a result of the fact that sonic velocity is first attained in the minimum section of a wind tunnel, and once attained, cannot be increased at that section no matter how much more power is applied. In this condition, the tunnel is described as choked. Wave reflection is undesirable because it does not simulate the free-flight condition. Instead, the shock waves are reflected off the tunnel walls, confusing the flow pattern in addition to the reflected waves striking the model.

Some of the methods touched on to alleviate or eliminate these problems were lining the test section walls to make sure that the minimum section falls at the model location and not at the model supports; "bump testing" to test small reflection plane models right up through the speed of sound; and the slotted test section, which consists of a closed-throat tunnel with slots every three or four inches around the test section. This procedure eliminates choking in the tunnel and permits tran-

sonic testing with no breaks in the Mach Number range. However, wave reflection is still not overcome by this means alone, and, although the solution to this problem has been found, it is still classified. The lecture was illustrated with slides, some of which depicted a large German wind tunnel under construction at the end of World War II. This tunnel was to have been powered by 100,000-hp. motors and would have been one of the largest tunnels in the world.

At the March 6 meeting the following officers were elected for the next school year: Robert Capria, Chairman; Howard Baum, Vice-Chairman; William Peschke, Treasurer; Allen J. Schneider, Recording Secretary; and Milton Cohen, Corresponding Secretary.

During the March 13 and March 26 meetings, arrangements were made for our field trip to the Grumman Aircraft Engineering Corporation on April 3.

HOWARD BAUM
Recording Secretary

Purdue University

On March 23, about 40 members of the Student Branch heard W. R. Laidlaw, Group Leader of Dynamics for North American Aviation's Columbus Division, deliver a speech on "Current Dynamics Problems of High-Speed Aircraft." Mr. Laidlaw discussed some of the dynamics problems of coupled yaw and pitch and some problems of flutter encountered at supersonic speeds. He also spoke on the difficulties involved in aerodynamic heating. Mr. Laidlaw then showed a movie taken with high-speed cameras mounted on a rocket sled with a vertical tail which was giving some flutter difficulties.

▸ On March 12, the Purdue Student Branch held a joint meeting with the Indianapolis Section of the IAS. About 80 members of the Indianapolis Section were conducted through the Purdue Rocket Laboratory, after which they attended a dinner in the Purdue Union Building.

M. J. Zucrow, Professor of Gas Turbines and Jet Propulsion at Purdue University, was the speaker of the evening. He covered some of the problems involved in the design of turbojet engines for propulsion of supersonic aircraft and indicated in some cases the regions in which the answers seem to lie. The supersonic aircraft turbojet power plant will probably have an afterburner with the associated variable-area exhaust exit, a relatively low compression ratio, and a variable-area intake, according to Dr. Zucrow.

DELBERT D. HOFFERTH
Secretary

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Rensselaer Polytechnic Institute

On March 14, the R.P.I. Student Branch was honored to have Igor A. Sikorsky, FIAS, as guest speaker. Mr. Sikorsky, Chief Aerodynamicist of Sikorsky Aircraft Division of United Aircraft Corporation, gave a paper entitled "The Evolution of the Helicopter."

Mr. Sikorsky indicated comparative trends in the fields of conventional and rotary-winged aircraft. He emphasized the role of the helicopter and illustrated its superiority in certain areas. A discussion followed Mr. Sikorsky's talk, and the meeting was concluded with a showing of a film on nonmilitary uses of the helicopter.

Over 160 members and guests were present.

PETER D. TANNEN
Assistant Secretary-Treasurer

San Diego State College

The Student Branch had as its guest speaker on April 10 Lt. Comdr. Robert Shackford, a graduate of M.I.T., who is now stationed at North Island Naval Air Base.

Speaking on "The Effects of Compressibility," he drew diagrams on the blackboard to show the flow around an airfoil at various speeds. At velocities near or at the speed of sound, he said, the air in front of an airfoil piles up in shock waves because it cannot get out of the way. At velocities under or over the speed of sound, the air can flow around the foil much more easily.

Commander Shackford exhibited a Navy film, *Compressibility Effects of Naval Aircraft*, which was made some time ago to show pilots how shock waves at near-sonic speed affect the controls and frame of a propeller-driven fighter in steep dives. The pilot must not dive his plane faster than its strength permits.

MICHAEL D. CHILCOTE, *Secretary*

Stevens Institute of Technology

Thirty-five members and guests saw a film, *The Jet Age Story*, at the March 6 meeting.

The Student Branch is planning a tour of Idlewild Airport on April 11.

GERARD FRIDSMA
Corresponding Secretary

Tri-State College

Student members of the Society of Automotive Engineers attended a joint meeting with us April 4 to listen to Don Ahrens, Project Engineer for the Cessna 310 (and a Tri-State graduate of '43). Mr. Ahrens gave a semitechnical talk on the birth of the Cessna 310.

Top photo shows missile tank constructed of two forged and machined end caps and center section of tubing. Middle photo shows assembled tank. The *Uniwelds* are located in the approximate center of the bright machined bands. Bottom photo shows a tank that has been pressured to bursting with 2½ times normal operating pressure. Note that the split crosses both weld planes with no tendency to divert and follow the weld—graphic proof of 100% parent metal weld strength.

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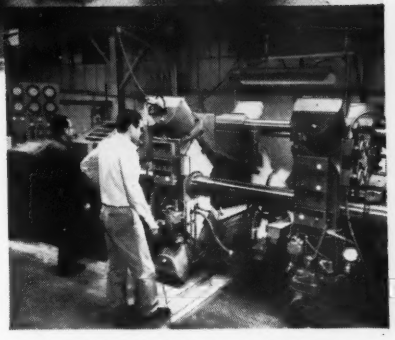

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Using slides to show the thrust augmentors, wheel assemblies, stress tests, fabrication methods, and various detailed parts, he explained the reasons behind each item. A motion picture demonstrated the performance and ease of flying the 310.

At a business meeting the following day, it was announced that the Student Branch would visit the Lewis Flight Propulsion Laboratory of NACA in Cleveland and the North American Aviation plant in Columbus on April 26. The meeting was rounded off with two NACA films, *Dynamic Stability and Control Characteristics of a Cascade-Wing Vertically Rising Airplane Model in Take-off, Landing, and Hovering Flight*" and *High-Speed Flight Research*.

▶ Starting the spring term with the usual coffee-and-doughnuts session on March 22, the old, new, and prospective members were treated to a travelogue by Professor Quintin Hawthorne. The trip was enhanced by color slides showing the beauty of the Alaskan territory and the airplanes used for cargo and general transportation.

New officers for the spring term are James Chapman, Chairman; Jules Dussia, Vice-Chairman; Ron Moyer, Secretary; Mel Bobb, Treasurer; Allen Ridley, Tri-Angle Reporter; and Richard Geide, Student Council Reporter.

R. JULES DUSSIA
Vice-Chairman

University of Colorado

Forty members attended the April 9 meeting to hear Web Moore, an Assistant Project Engineer of The Cessna Aircraft Company. Mr. Moore discussed the design of the CH-1 helicopter and the T-37 jet trainer. Slides and movies were shown to illustrate both aircraft. The helicopter, he said, has been flown from the top of Pike's Peak —an altitude of 14,000 ft.

The following officers were elected for next year: Chairman, Dennis Samson; Vice-Chairman, Mike Adams; Secretary, Dave Ellis; and Treasurer, Dave Golob.

The students are designing and building a model guided missile to be displayed during Engineering Days, April 20 and 21. The Student Branch held a dinner dance at the Buckley Naval Officers Club in March.

HAROLD J. BARTLESON, *Secretary*

University of Florida

The success of the aeronautical exhibits at the Engineers' Fair was discussed at the March 19 meeting. The IAS exhibits placed a close second to those of the Civil Engineering Department. The supersonic wind tunnel was given an "outstanding exhibit" award that has been framed by the Student Branch. Much of the success of the exhibits was credited to informal discussions with the public by aeronautical engineering students during the guided tours around the hangar.

Frank Castellon is in charge of arrangements for the IAS picnic, and Arnold Wolff was appointed to draw up a list of suggestions.

Dick Atkins was congratulated at the meeting for his work in editing the *Mach Buster*, the official publication of the Florida Student Branch of the IAS.

Shirley Van Patten conducted a discussion of the definition of static lift. No definition was decided upon, but many ideas were exchanged.

The meeting closed with a film entitled *Ficon*. It was produced by Convair as a report on the B-36—F-84F parasite program.

JOHN DAVID ANDERSON
Recording Secretary

University of Illinois

On April 11, the Student Branch met to hear Harold T. Luskin, Assistant Chief of Aerodynamics of the Douglas Aircraft Company, talk on "Fundamental Problems in Aeronautical Engineering." Approximately 100 members attended.

Mr. Luskin took a fresh view of these problems. He did not just mention records in speed or endurance of present airplanes, but he saw all aircraft as vehicles designed to produce a number of ton-miles per dollar. On this basis, the subsonic and supersonic aircraft, as well as the hypersonic rocket, were compared regarding speed, range, payload, cost factor versus speed, and cost factor versus range. At the present stage of aeronautics, the subsonic transport and cargo aircraft are still by far the most economical.

In the ensuing discussion, Mr. Luskin predicted that, just as present airplanes were able to capture about 70 per cent of all first-class passengers from surface transportation, the development of a successful atomic plane will capture a like share of the freight-hauling business.

The second part of Mr. Luskin's talk dealt with one specific problem—the suction of pebbles and other foreign matter from the ground by jet-engine intakes. The velocities and forces calculated by the perfect-fluid theory were found inadequate, and no solution was discovered until tests showed that a vortex filament formed on the ground and disappeared into the intake. Although several similar problems like a tornado, vortices behind a weir and above a cliff, and local stalling at a nacelle on a sweptback wing are observed, no "classic" theory accounts for these vortices.

FRED O. MARTIKAN, *Secretary*

University of Kentucky

Student members and their guests heard an address by Thomas H. Clore, a graduate student, at the March meeting.

Mr. Clore discussed the work that has been done on parachute disreefing devices by German scientists and also what has been and is being done on this project at the Aeronautical Research Laboratory.

Mr. Clore is also scheduled to discuss this project at the Regional Conference in Georgia in April.

WALTER J. BLACKSON
Secretary-Treasurer

University of Maryland

Twelve student members and five members of the faculty attended a meeting of the Student Branch on April 10. The purpose of this meeting was to hold the Student Branch Paper Competition. Gerald Corning, Shan-Fu Shen, and Lee Wintergrad were the faculty members who served as judges.

The winning paper, "The Effective Thickness of Built-Up Flanges Subjected to Crippling Loading," was presented by Charles O. Johnson and Edward C. Wood. As a prize, Mr. Johnson and Mr. Wood will each receive a subscription to the JOURNAL OF THE AERONAUTICAL SCIENCES and the AERONAUTICAL ENGINEERING REVIEW. Other papers presented were "Metal-to-Metal Bonding" by Paul D. Fisher and Stanley T. Corbett, "Some Effects of Supersonic Jet Stream Exhausted over Thin Curved Airfoils" by Stanley T. Piszkin and Charles G. Stouffer, "A Comparison of Methods of Determining the Flow About a Body" by Herbert E. Hunter and Robert L. Velebny, and "Investigation of the Effects of Trailing-Edge Roughness on the Drag Characteristics of the NACA 0015 Airfoil" by Tunney Oydna and Juri Kork.

H. E. HUNTER, *Secretary*

University of Oklahoma

Two student papers were presented at the April 10 meeting in preparation for the coming Southwestern Regional Student Conference in Dallas. Jerry Mrazek offered a paper entitled "Some Stability Problems in the Transonic Range" for entrance in the undergraduate division. In the graduate division, Hugh Weston read his paper on "A Matrix Method for Analyzing Fuselage Frames."

A color movie, *Flight Test and Performance of the P2V-1 Trainer*, bor-

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rowed from Lockheed Aircraft Corporation was shown. Forty members were present.

THOMAS B. SHOEBOTHAM
Secretary-Treasurer

Virginia Polytechnic Institute

The following officers were elected at the April 3 meeting: Chairman, S. J. Harris; Vice-Chairman, J. C. South; Secretary, F. W. Johnson; and Treasurer, J. C. Patterson. All the new officers are juniors in Aeronautical Engineering.

Plans were discussed for representation at the IAS Regional Student Conferences at University of Maryland and Georgia Institute of Technology. The Student Branch also will participate in an Engineering Emphasis Program to be held on the campus April 23–28.

F. WENDELL JOHNSON, *Secretary*

Wayne University

At the March 29 meeting, all seniors were urged to submit technical papers to be entered in the forthcoming IAS contest. The best paper will be presented at the annual Regional Student Paper Contest May 10 at the University of Detroit. It was suggested that this joint meeting be made open to wives and friends of attending IAS members.

Final arrangements were made for a trip to the General Motors Proving Grounds on April 4.

It was announced by Frank Ottati, IAS representative to the Student Engineering Board, that the spring Engineering Orientation Class would tour the department on April 9. Tentative plans for the tour include (1) a demonstration of the airflow around variously shaped objects, using a smoke tunnel and water table; (2) a demonstration of the subsonic, transonic, and supersonic wind tunnels; and (3) a demonstration of the apparatus used to view shock waves.

The meeting was closed with a showing of the film *New Power for Flight*, produced by General Motors Corporation, which dealt with the development of turboprop engines and aircraft.

EDWARD R. COLEMAN, *Secretary*

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Imai, Isao, D.Sc., Prof., Dept. of Physics, Univ. of Tokyo; Visiting Research Prof., Institute for Fluid Dynamics & Applied Math., Univ. of Maryland.

Jackson, Charles, M.S., Struct. Dynamics Unit Chief, Boeing Airplane Co. (Wichita).

Transferred to Associate Fellow Grade

Boley, Bruno A., Ph.D. in Ae.E., Assoc. Prof., Institute of Flight Struct., Columbia Univ.

Boxer, Emanuel, M.S. in Ae.E., Head, Supersonic Compressor Sect., Cascade Aerodynamics Branch, NACA, Langley AFB.

Branahl, Erwin F., M.S., Chief Aero. Mech. Engr., Aerodynamics, Dynamics, Struct. Weights & Thermodynamics Depts., McDonnell Aircraft Corp.

Christenson, Charles H., B. of Ae.E., Preliminary Design Engr., Lockheed Aircraft Corp. (Burbank).

Hirsch, Harold, B.S. in C.E., Chief Helicopter Engr., Helicopter Engrg. Dept., Aircraft Div., Hughes Tool Co.

Smith, Lee H., Dir.—Field Service, Military Relations & Customer Service, Northrop Aircraft, Inc.

Elected to MEMBER Grade

Andrew, Lowell V., B.S., Dynamics Engr., Flutter Analyst, Convair, San Diego, A Div. of General Dynamics Corp.

Band, Edward G. U., M.S. Fluid Dynamics, Sr. Hydrodynamicist, The Glenn L. Martin Co.

Barkofsky, Ernest C., M.Ph., Head—Ballistics Instrument Branch, U.S. Naval Ordnance Test Station (China Lake).

Baxter, Richard D., B.S., Flight Test Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Beder, Earl, M.S.M.E., Aerodynamics Engr., Asst. Head, Supersonics Group, Propulsion Research Corp.

Bernhart, John H., B.S. in M.E., Specialist—Aircraft Engines, General Electric Co. (Wash., D.C.).

Berninger, Clifford F., M.S. in M.E., Principal Research Engr., Gas Dynamics Branch, Republic Aviation Corp.

Bradley, Fred E., A.A. in Ae.E., Air Loads Engr., Helicopter Engrg. Div., McDonnell Aircraft Corp.

Brock, F. J., M.S. in Physics & Math., Test Engr. & Supvr., Devel. Test Group, McDonnell Aircraft Corp.

Bruner, Frederick W., M.S. in Ae.E., Lt. Col., USAF; Chief, C-130 Weapon System Proj. Office, ARDC, Det. 1, W-P AFB.

Bryant, Glenn D., M.S. in Ae.E., Aero. Engr., Aerophysics Dept., Mississippi State College.

Cathcart, John W., B.S. in Ae.E., Design Engr., McDonnell Aircraft Corp.

Creswell, James C., B. of Engrg., Design Engr. in charge of the Systems Analysis Group, Equipment Sect., Engrg. Dept., Douglas Aircraft Co., Inc. (Long Beach).

Cronin, Walter F., B.S.E.E., District Mgr.—Aviation & Defense Indus., General Electric Co. (Seattle).

Danielsen, Donald P., B.S., Designer "A," Douglas Aircraft Co., Inc. (Long Beach).

Devlin, Howard A., B.S. in Ae.E., Military Sales Engr., Factory Rep., Joy Manufacturing Co.

Durgin, Frank H., S.M., Proj. Engr.—Research & Wind-Tunnel Testing, Naval Supersonic Lab., Massachusetts Institute of Technology.

Flesher, Joseph H., Jr., Design Specialist, The Glenn L. Martin Co.

Fraser, Douglas O., Asst.—Aero. Advisory Services, English Electric Co., Ltd. (England).

Freeburg, David H., Design Group Engr., McDonnell Aircraft Corp.

Gaydos, M. Edward, B.A.E., Supervising Flight Test Engr., CAA (Jamaica).

Gittens, E. Donald, B.S., V-P & Chief Engr., Arma Div., American Bosch Arma Corp.

Goehring, William F., B. of M.E., Fuselage Lead Designer, Chance Vought Aircraft, Inc.

Hart, Kenneth G., M.S. Engrg., Research Engr., Northrop Aircraft, Inc.

Hogan, Oliver D., Mech. Sect. Supvr., Physical Lab., McDonnell Aircraft Corp.

Holzwarth, Robert W., B.S., Design Engr., McDonnell Aircraft Corp.

Huseman, Charles F., Design Engr., McDonnell Aircraft Corp.

Kelly, Howard R., M.S., Head—Aerodynamics Branch, U.S. Naval Ordnance Test Station (China Lake).

Kolb, James N., B.S. in Ae.E., Flight Test Engr., McDonnell Aircraft Corp.

Krisilas, John G., M.S.M.E., Thermodynamics Engr., Lockheed Aircraft Corp. (Burbank).

Landberg, Stanley H., B.S. in Ae.E., Engr.—Aerodynamicist, Convair, Pomona, A Div. of General Dynamics Corp.

Lundberg, Delton M., B. of Ae.E., Mgr.—Production Flight Test Sect. & West Coast Rep., The Glenn L. Martin Co.

Malott, Donald M., B.S.M.E., Experimental Engr.—Power Turbine Test Proj., Allison Div., General Motors Corp

Michels, Carl J., M.S.M.E., Northeast District Mgr., Dalmo Victor Co., Div. of Textron American Co.

Michelson, Louis, B.S. in Physics, Mgr.—Rocket Engine Sect., Devel. Dept., AGT Div., General Electric Co.

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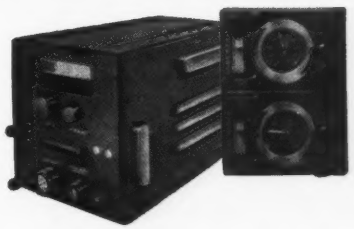

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Miller, R. J., B.S.E.E., Mgr.—Aircraft Equipment Dept., Chatham Electronics Div., Gera Corp.

Mitchell, Myles B., M.S., Design Engr., McDonnell Aircraft Corp.

Montgomery, Lawrence C., B.S.M.E., Design & Devel. Engr., Jet Propulsion Lab., California Institute of Technology.

Neigel, Joseph A., Assoc. M.E., Sr. Supervisory Engr., Walter Kidde & Co., Inc.

Pentecost, Horace T., Design Engr., Consolidated Western Steel Div., U.S. Steel Corp.

Plouse, Henry, B.S. in Ae.E., Struct. Engr., Fuselage Group, Douglas Aircraft Co., Inc. (Long Beach).

Poladian, Robert, B.S., Capt., USAF; Design Devel. Aero. Engr.—Chief, Devel. Maint. Div., Directorate of Readiness Inspection, Hqs. Command, Norton AFB.

Pratt, George L., B. of Ae.E., Aero. Research Scientist, Proj. Engr., NACA, Langley AFB.

Rahrig, Thomas F., B.S., Stress Analyst, Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.

Ramsey, Cleve M., Cockpit Group Engr., McDonnell Aircraft Corp.

Schenk, Clinton D., Jr., Stress Analyst "A," Boeing Airplane Co. (Seattle).

Schwarz, Edward T., B.S., Group Leader, Stress Analysis Group, Struct. Dept., McDonnell Aircraft Corp.

Shafer, H. Jerome, M.S.E., Sr. Lecturer & Acting Head, Dept. of Aero. Engrg., Technion, Israel Institute of Technology.

Shepherd, Roland P., M.S., Research Engr. "A," Devel. Test Group, Douglas Aircraft Co., Inc. (Tulsa).

Torgerson, Arnold S., B.S., Engrg., Asst. Proj. Engr., McDonnell Aircraft Corp.

Uchida, Shigeo, Dr. of Engrg., Assoc. Prof. & Dir.—Research Program, Lab. of Applied Dynamics, Institute of Science & Technology, Univ. of Tokyo.

White, H. G. R., Sr. Engr., Research Lab., Cook Electric Co.

White, Robert W., Jr. Design Engr., McDonnell Aircraft Corp.

Woollett, Richard R., M.S. Physics, Aero Research Scientist, Proj. Engr., Propulsion Aerodynamics Sect., NACA, Flight Propulsion Lab.

Wulff, Henry R., Design Engr., McDonnell Aircraft Corp.

Transferred to MEMBER Grade

Alley, Donald J., M.A.E., Sr. Dynamic Engr., Convair, San Diego, A Div. of General Dynamics Corp.

Bijoor, Ramesh G., B. of Ae.E., Engr. responsible for preparation of aerodynamic data, Canadian Aviation Electronics, Ltd.

Cole, Donald M., Jr., S.B. in Ae.E., Supvr.—Struct. & Armament Test, Northrop Aircraft, Inc.

Curren, Arthur N., B.S.M.E., Aero. Research Scientist, NACA, Lewis Flight Propulsion Lab.

Epperson, Thomas M., B.S. in Aero., Customer Service Rep. & Group Leader—

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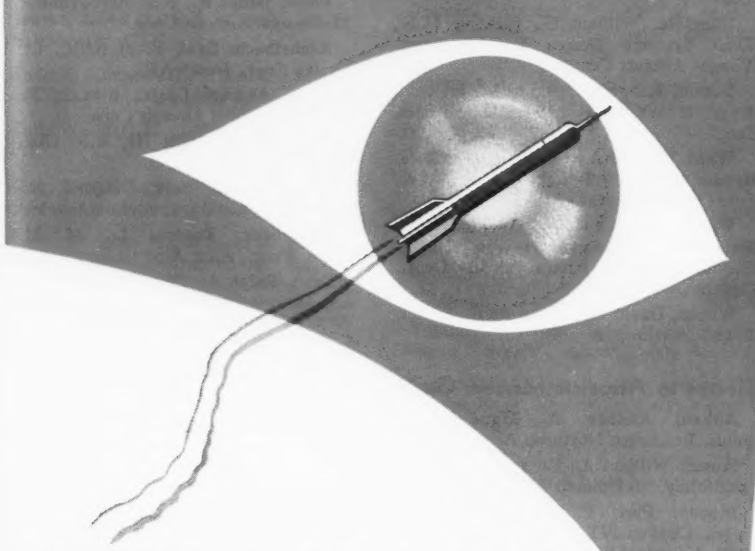

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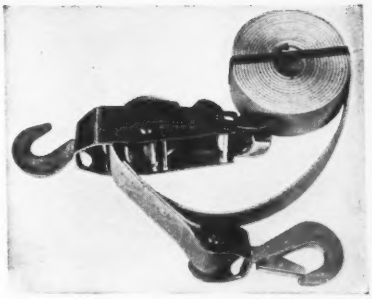

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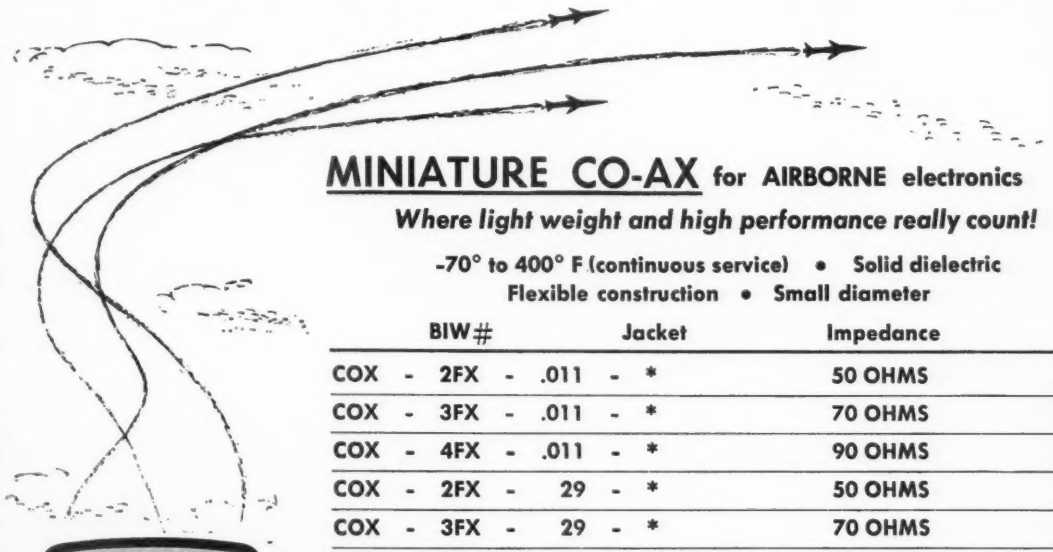

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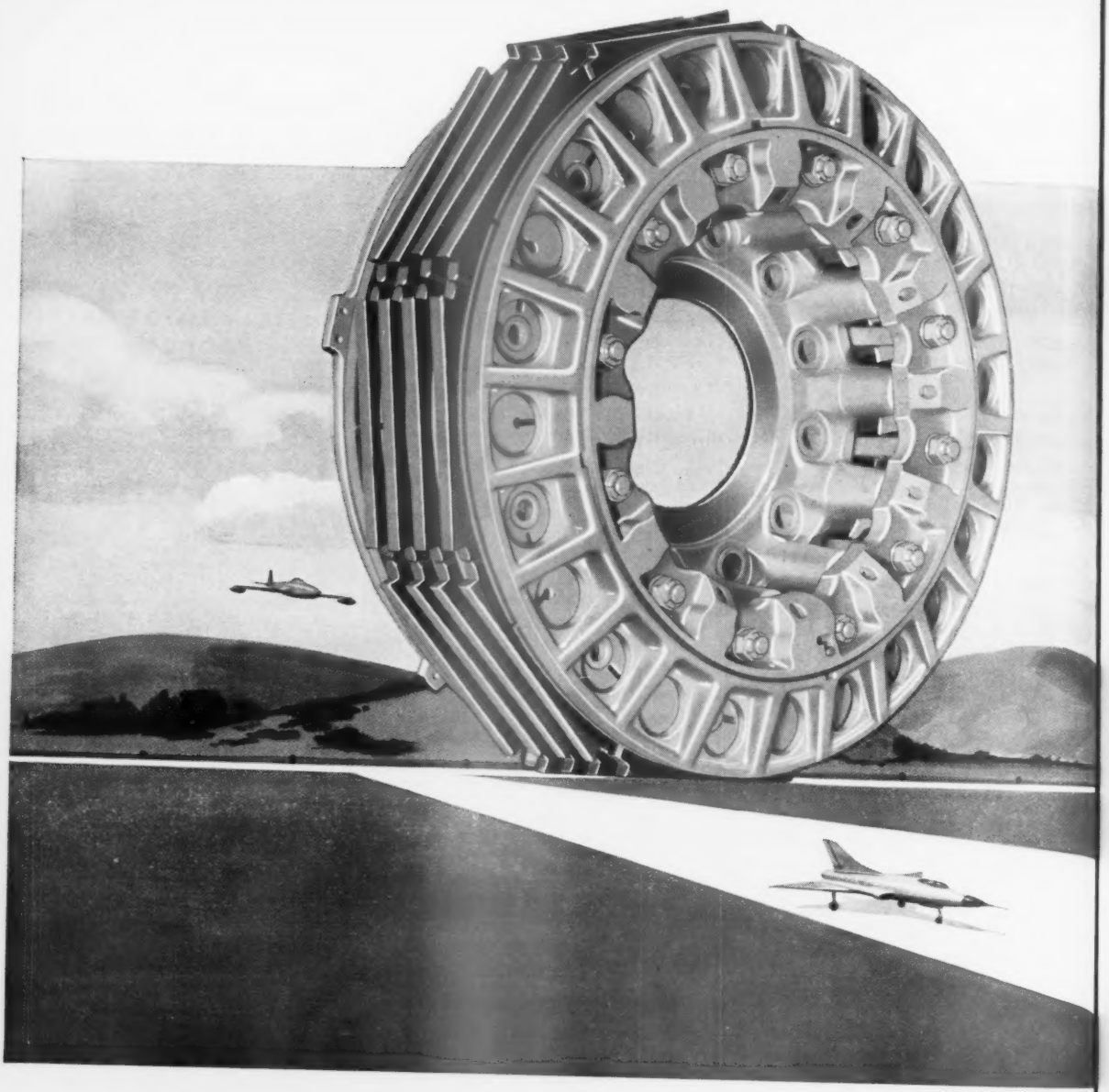

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Acoustics, Sound, & Noise

Acoustics of a Nonhomogeneous Moving Medium. D. I. Blokhintsev. (Moscow, Gostekhizdat, 1946). *U.S., NACA TM 1399*, Feb., 1956. 198 pp. 55 refs. Translation. Analysis of sound propagation and reception in a moving medium, including fundamental acoustic equations, sound propagation in the atmosphere and water, a moving sound source such as a source at supersonic velocity, a general formula for the Doppler effect, and sound excitation by flow and action of a sound receiver in a stream.

An Experimental Study of the Response of Simple Panels to Intense Acoustic Loading. Leslie W. Lassiter, Robert W. Hess, and Harvey H. Hubbard. *IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 632.* 11 pp. Members, $0.35; nonmembers, $0.75. Results of the investigation of fatigue life and crack growth, with stress data for panels exposed to noise from a jet engine at levels of approximately 160 db. as well as to nominal levels of discrete and random noise in controlled laboratory tests.

Noise, Vibration, and Aircraft Structures. Arthur A. Regier. *IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 631.* 15 pp. 44 refs. Members, $0.50; nonmembers, $0.85. Review of the basic factors in terms of response of systems to various types of inputs, near field characteristics of various noise sources, vibration modes, and fatigue.

On the Aerodynamic Surface Sound from a Plane Turbulent Boundary Layer. O. M. Phillips. *Proc. Royal Soc. (London), Ser. A*, Feb. 21, 1956, pp. 327–335.

Supersonic Bangs. I. P. Sambasiva Rao. *Aero. Quart.*, Feb., 1956, pp. 21–44. Development of a nonlinear theory of supersonic bangs from an accelerated body using an extension of the Whitham method, to determine the strength of the bow shock indicating the effect of acceleration on the pressure rise at large distances from the nose for Mach Numbers near unity.

Aerodynamics

Applied Aerodynamics and Flight Mechanics. W. Bailey Oswald. *J. Aero. Sci.*, May, 1956, pp. 469–484. 16 refs. Analysis of the von Kármán investigations in terms of design applications as related to such specific problems as: turbulent skin-friction variation with Reynolds Number; turbulent skin-friction variation with Mach Number into the supersonic speed regime; pressure coefficient variation with Mach Number in the subsonic speed regime; transonic similarity rules for correlating information on thin bodies in the transonic speed range; and nose shape for optimum pressure drag of slender bodies of revolution at supersonic speeds.

Hydrodynamics—A Review of von Kármán's Contributions. Arthur T. Ippen. *J. Aero. Sci.*, May, 1956, pp. 438–443, 499. 25 refs. Discussion of the boundary layer and turbulence concepts, von Kármán vortex trails, impact of seaplane floats on water, hydraulic analogy to supersonic motion, and developments in hydraulic machinery.

Some Problems in Aerodynamics and Their Solution by Electrical Analogy. D. Küchemann and S. C. Redshaw. *J. RAeS*, Mar., 1956, pp. 191–197. 83 refs. Survey of aerodynamic phenomena including two- and three-dimensional airfoils, interference, and potential flow problems.

Boundary Layer

Experimental Investigation of Leading Edge Shock Wave—Boundary Layer Interaction at Hypersonic Speeds. James M. Kendall, Jr. *GALCIT Hypersonic Project Memo. 30*, Jan., 1956. 19 pp. 14 refs.

Formulae and Approximations for Aerodynamic Heating Rates in High Speed Flight. Appendix I—**Factors Influencing Transition.** R. J. Monaghan. *Gt. Brit., RAE TN Aero. 2407*, Oct., 1955. 53 pp. 19 refs. Derivation of formulas to estimate local and mean heat flow rates, with laminar or turbulent boundary layers related to transitional problems of laminar to turbulent flow, taking into account the effects of Mach Number, surface temperature, altitude, and Reynolds Number on heat flow rates, and the effects of radiation and the time required for the skin to reach the resulting equilibrium at constant Mach Number and altitude.

Heat Transfer Characteristics of a Hemisphere Cylinder at Hypersonic Mach Numbers. Eva M. Winkler and J. E. Danberg. *IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 622.* 15 pp. Members, $0.50; nonmembers, $0.85. Results of the USAF-NAVORD-sponsored experimental investigation in the NOL Hypersonic Tunnel at Mach Numbers up to $M = 8$, free-stream Reynolds Numbers based on model diameter in the range from 70,000 to 400,000, and the wall to stagnation temperature ratios from 0.43 to 0.75, with data evaluated from temperature differences across the wall on a cooled model under steady-state conditions.

The Resistance Law for Rough Plates. L. Prandtl and H. Schlichting. (*Werft-Reederei-Hafen*, Berlin, Jan., 1934). *U.S., Navy Dept., David W. Taylor Model Basin, Transl. 258*, Sept., 1955. 13 pp. Development of a theory based on Nikuradze results of flow through artificially roughened pipes.

Some Experimental Studies of the Separation of Supersonic Turbulent Boundary Layers. Seymour M. Bogdonoff. *Princeton U. Dept. Aero. Eng., Rep. 336*, June, 1955. 18 pp. 28 refs. Summary of ONR-ARDC-sponsored test results.

Some Features of Boundary Layers and Transition to Turbulent Flow. Arnold M. Kuethe. *J. Aero. Sci.*, May, 1956, pp. 444–452, 506. 85 refs. Review of investigations of the problem, with experimental results on transition in Poiseuille flow in a tube including measurements of the transition excited by the annular wake behind a ring airfoil and oscillographic recordings of the velocity fluctuations in the flow for several disturbance amplitudes.

The Three-Dimensional Laminar Boundary Layer Flow About a Yawed Ellipsoid at Zero Incidence. Appendix I—**The Value of the Parameter σ in the Stagnation-Point for an Infinite Elliptic Cylinder.** Appendix II. J. A. Zaat, E. Van Spiegel, and R. Timman. *Netherlands, NLL Rep F. 165*, Jan., 1955. 20 pp. Calculations using the Timman theory as applied to the case of sweptback wings, with the momentum equations replaced by a set of two first-order partial differential equations in two unknown functions.

Fluid Flow in Regions Bounded by Porous Surfaces. Geoffrey Taylor. *Proc. Royal Soc. (London), Ser. A*, Mar. 6, 1956, pp. 456–475. Investigation of the aerodynamic effects of blowing air into or sucking away boundary layers, under the assumption that the rate of discharge through the pores is under experimental control, applied to the case of flow through a wedge, cone, and cylinder, with the resistance of the material proportional to the square of the velocity through it, using an integral equation.

Grenzschichsteuerung in der Praxis. Gustav Victor Lachmann. *ZFW*, Jan.–Feb., 1956, pp. 9–14. In German. Critical analysis of methods existing or in development used to prevent boundary-layer separation on airfoils and the increase of lift due to flaps by sucking or blowing.

Grenzschichtabsaugung mittels Abgasstrahls. K. Morghen and K. Rothe. *ZFW*, Nov., 1955, pp. 371–373. In German. Experimental investigation of the boundary layer removal, with tests on an exhaust jet pump consisting of a jet engine fitted with a mixing tube to determine the dimensions of the mixing tube as a function of the mass of air subjected to suction and the change in the effective thrust in order to remove the boundary layer.

Control Surfaces

Early Thoughts on the Jet Flap. B. S. Stratford. *Aero. Quart.*, Feb., 1956, pp. 45–59. Description of the stages in the proving of the basic principles and in the development of the first quantitative theory through the experimentally confirmed prediction that the lift would be induced on the airfoil by a two-dimensional jet deflected from the trailing edge; that the magnitude of the total lift would be of the order of four times the direct jet lift; and that, ideally, the forward thrust on the airfoil would be independent of the deflection angle of the jet.

Mixing and the Jet Flap. Appendix I—**The Momentum Method; an Alternative Approach to the Mixing Between the Jet and the Main Stream.** Appendix II—**Considerations of Sinks and Sources in Order to Visualize the Flow—Further Details.** Appendix III—**Mixing Between the Aerofoil Boundary Layers and the Jet—Further Details.** B. S. Stratford and N. A. Dimmock. *Gt. Brit., NGTE Memo. M. 250*, Oct., 1955. 45 pp. Results of theoretical and experimental investigations of the high lift technique indicating the possible reduction of thrust loss through the use of by-pass engines and a shrouded jet flap at take-off.

The Pressure Distribution on an Unswept Wing with Various Arrangements of Split Flap. J. A. Lawford. *Gt. Brit., RAE TN Aero. 2384*, July, 1955. 62 pp. Results of tests in the 4 × 3 in. low turbulence wind tunnel on an RAE 101 air-

foil section having a five per cent chord flap at varying angles of incidence, angle, aspect ratio, and chordwise station.

Fluid Mechanics & Aerodynamic Theory

Examples Illustrating Expansion Procedures for the Navier-Stokes Equations. P. A. Lagerstrom and J. D. Cole. (*J. Rational Mech. & Anal.*, Nov., 1955, pp. 817–882.) *GALCIT Pub. 384*, 1955. 65 pp. 14 refs. Reprint. Study of analytical approximation methods used in the theory of viscous incompressible flow according to the Prandtl, Stokes, and Oseen approaches and applied to such fundamental flow problems as the case of an immersed infinitely long circular cylinder suddenly started from an initial state of rest analyzed as a generalization of the Rayleigh sliding-expanding cylinder problem.

Turbulence Measurements in Free Surface Flow with an Impact Tube-Pressure Transducer Combination. Appendix A—**Detailed Analysis of Mechanical System of Gage 1-A.** Appendix B. Appendix C—**Design and Performance Characteristics of Gage with Piezoelectric Ceramic Pressure Transducer.** A. T. Ippen, R. S. Tankin, and F. Raichlen. *M.I.T. Hydrodynamics Lab. TR 20*, July, 1955. 96 pp. 23 refs. Results of an ONR-sponsored theoretical and experimental investigation into the applicability of an impact tube in combination with a capacitance-type pressure transducer to measure mean turbulence properties.

Bodies of Revolution Having Minimum Drag at High Supersonic Airspeeds. Appendix A—**Estimated Effect of Centrifugal Forces on Surface Pressure Coefficients.** Appendix B—**Calculations of Minimum-Drag Bodies, with Consideration of Centrifugal Forces in the Disturbed Flow Field.** A. J. Eggers, Jr., Meyer M. Resnikoff, and David H. Dennis. U.S., NACA TN 3666, Feb., 1956. 38 pp. 18 refs.

Flow Separation in Three Dimensions. E. C. Maskell. *Gt. Brit., RAE Rep. Aero. 2565*, Nov., 1955. 20 pp. Development of a generalized concept of the separation phenomena, with a determination of conditions in the vicinity of the line of separation.

Formation of a Vortex at the Edge of a Plate. Leo Anton. (*Ing.-Arch.*, 1939, pp. 411–427.) *U.S., NACA TM 1398*, Mar., 1956. 36 pp. Translation. Investigation of the flow about a plate of infinite width represented as a potential flow with discontinuity surfaces extending from the plate edges applied to the case of a plate perpendicular to the approaching flow and forming a right angle.

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Inviscid Hypersonic Flow Over Blunt-Nosed Slender Bodies. Lester Lees *GALCIT Memo. 31*, Feb. 1, 1956. 12 pp. 10 refs. Investigation of the applicability of Taylor and Lin results of studies of the shape of bow shock wave behind an unyawed, axially-symmetric body travelling at a uniform hypersonic velocity, to the problems of a shock wave generated by a blunt nose of finite radius on an unyawed slender body.

A Method for Calculating the Contour of Bodies of Revolution with a Prescribed Pressure Gradient at Supersonic Speed with Experimental Verification. Appendix A—**Equation for Determining the Flow Properties of a Field Point.** Appendix B—**Method of Determining the Transitional Reynolds Number of the $M = 3.13$ Nozzle.** Paige B. Burbank. *U.S., NACA TN 3555*, Mar., 1956. 64 pp.

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An Experimental Investigation of a Thick-Aerofoil Nozzle Cascade. S. J. Andrews and N. W. Schofield. *Gt. Brit., ARC R&M 2883*, 1956. 13 pp. BIS, New York. $1.00. Study of the flow over the blade surfaces applying the evaporation of crystals, lamp-black deposit, surface total-head measurement and stethoscope search tube methods to determine the transition point, with a calculation of the point of instability from the velocity and boundary-layer momentum-thickness distribution using the Polhausen criterion; and theoretical estimates of the effect of the thick trailing edge to evaluate the heat-transfer properties and efficiency of airfoil-section blades with the thickness maintained well toward the trailing edge.

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The Effect of Character of Surface Roughness on Velocity Distribution and Boundary Resistance. Harry H. Ambrose. *U. Tenn. Dept. Civ. Eng., Final Rep.* ONR-sponsored experimental investigation of turbulent flow through pipes with cylindrical depressions or projections as roughness elements.

Note on the Motion Inside a Region of Recirculation (Cavity Flow). H. B. Squire. *J. RAeS*, Mar., 1956, pp. 203–205. Analysis of the problem, based on the Batchelor free convection theory, indicating that the flow in a region of recirculation may be divided into a core, with constant vorticity and surrounding boundary layer. Includes an approximate solution for the flow inside a circular cylinder with partly fixed and partly moving walls.

Some Experiments on the Secondary Flow in Pipe Bends. J. H. Horlock. *Proc. Royal Soc. (London), Ser. A*, Feb. 21, 1956, pp. 335–346. Analysis, under the assumption of a sine curve for the center line of the bend, of the general behavior of the flow, solved as a nonlinear differential equation, with a variety of solutions obtained for different entry conditions and compared with experimental data.

The Influence of Turbojet Airflow on the Aerodynamic Design of Airplanes. Harold Luskin and Harold Klein. *Douglas Rep. SM-19111*, June, 1955. 42 pp. 11 refs. Application of momentum and angular momentum theorems to determine the longitudinal forces and moments acting on a turbojet airplane.

Perturbations of Supersonic Nozzle Flows. R. E. Meyer. *Aero. Quart.*, Feb., 1956, pp. 71–84. Extension of the Meyer and Holt perturbation theory to general, steady, supersonic, two-dimensional, isentropic and irrotational flow of a perfect gas in order to determine, in terms of the nozzle design requirements, the effect on the velocity distribution in the test rhombus of a change in the stagnation pressure in order to change the Reynolds Number, or of a slight tilting of the liners to change the Mach Number slightly; and the error admissible in the estimate of boundary-layer corrections and, generally, the tolerances admissible regarding the shape of the liners.

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Stability & Control

A Flight Evaluation of the Longitudinal Stability Characteristics Associated with the Pitch-Up of a Swept-Wing Airplane in Maneuvering Flight at Transonic Speeds. Appendix A—**Additional Longitudinal-Stability and -Control Characteristics.** Appendix B—**Elevator-Angle Calculations.** Seth B. Anderson and Richard S. Bray. *U.S., NACA Rep. 1237*, 1955. 12 pp. Supt. of Doc., Wash. $0.20.

Wings & Airfoils

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Kritische Bemerkungen zur dreidimensionalen Tragflächentheorie im Unterschallgebiet. Hans Georg Küssner. *ZFW*, Jan.–Feb., 1956, pp. 21–26. 13 refs. Analysis of methods for the approximate solution of the boundary value problem of the three-dimensional lifting surface theory in subsonic region.

Some Properties of Curved Planforms for Sweptback Wings at Subsonic and Supersonic Speeds. G. G. Brebner and W. T. Lord. *Gt. Brit., RAE TN Aero. 2417*, Nov., 1955. 17 pp. 16 refs. Summary of the subsonic theory of curved plan forms and a presentation of results of preliminary investigations of the wave drag of several swept wings similar to subsonic designs.

Some Recent Developments in Airfoil Theory. W. R. Sears. *J. Aero. Sci.*, May, 1956, pp. 490–499. 43 refs. Review of investigations of: the theory of profiles with boundary layers in steady flow; the theory of profiles with boundary layers in unsteady flow, including extensions of unsteady airfoil theory; the theory of wings with leading-edge separation; and the Prandtl wing theory applied to partially stalled wings.

The Flow Around a Supersonic Aerofoil. J. J. Mahony and P. R. Skeat. *Australia, ARL AN 147*, Oct., 1955. 15 pp. Derivation of an approximate solution for the pressure distribution in rotational supersonic flow of a perfect inviscid gas about a two-dimensional sharp-nosed biconvex airfoil with a ten per cent thickness ratio.

A Review of Source Superposition and Conical Flow Methods in Supersonic Wing Theory. H. J. Stewart. *J. Aero. Sci.*, May, 1956, pp. 507–516. 28 refs. Analysis of developments based on the von Kármán application of the linearized theory to axially symmetric bodies, the Busemann introduction of the concept of a conical flow, the von Kármán general theory of the drag of slender axially symmetric bodies, and the similarity theory for the linearized equation of motion. Includes a study of the basic variations involved.

The Calculation of the Spanwise Loading of Sweptback Wings with Flaps or All-Moving Tips at Subsonic Speeds. G. G. Brebner and D. A. Lemaire. *Gt. Brit., RAE Rep. Aero. 2553*, Sept., 1955. 54 pp. 18 refs. Analysis of results of Duquenne and Grandjean electric tank tests on 45° sweptback wings with trailing-edge flaps to develop a method for the calculation of the spanwise loading in terms of the effect of sweep on the equivalent incidence of a section with flap, on the downwash factor, and on the spanwise loading distribution with an incidence discontinuity.

Effect of Ground Interference on the Aerodynamic and Flow Characteristics of a 42° Sweptback Wing at Reynolds Numbers up to 6.8×10^6. Appendix—**Method of Downwash Calculations.** G. Chester Furlong and Thomas V. Bollech. *U.S., NACA Rep. 1218*, 1955. 60 pp. 12 refs. Supt. of Doc., Wash. $0.45.

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Zur Berechnung der Zirkulationsverteilung bei der ebenen, inkompressiblen Umströmung dünner Flügelprofile. W. Kaufmann. *ZFW*, Nov., 1955, pp. 373–376. In German. Investigation of the chordwise pressure distribution of thin airfoils with moderate camber in plane incompressible flow using the Multhopp formula of interpolation for the estimation of the span loading pressure distribution of a finite wing.

A Flat Wing with Sharp Edges in a Supersonic Stream. A. E. Donov. (*Izvestia Akademii Nauk*, USSR, 1939.) *U.S., NACA TM 1394*, Mar., 1956. 48 pp. Translation. Development of an approximate solution of the problem of a two-dimensional steady supersonic stream of ideal gas, neglecting the heat conduction, around a thin wing at small angles of attack as related to Ackeret, Prandtl, and Busemann results based on the potential supersonic theory.

Aeroelasticity

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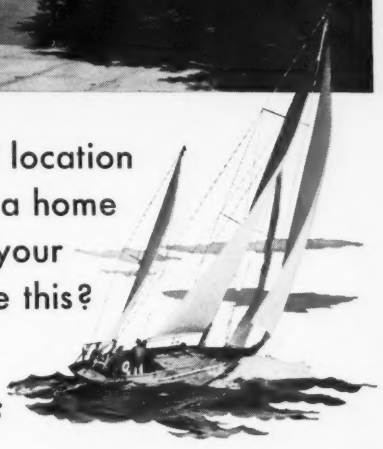

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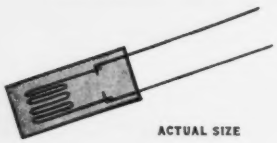

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The General Theory of "Hysteretic Damping." II. R. E. D. Bishop. *Aero. Quart.*, Feb., 1956, pp. 60–70. Formulation of a mathematical theory of small hysteretically damped vibrations, using Lagrange equations with a new type of dissipation function, for systems having more than a single degree of freedom, in terms of generalized forces and displacements as related to the Rayleigh theory of viscous damping.

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Oscillatory Aerodynamic Loads on Low-Aspect-Ratio Wings in Subsonic Flow. I—Methods of Calculation and Comparison with Measured Loads. Appendix A—**Integrals for Pressure-Downwash Relation.** Appendix B—**Numerical Tabulations of Certain Integrals.** Appendix C—**Representation of the Pressure Distribution and Its Derivatives, in Terms of Its Point Values.** Appendix D—**Numerical Evaluation of Generalized Forces.** Appendix E—**Solution of the Pressure-Downwash Equation on a Digital Computer.** Appendix F—**Literal Expressions for Generalized Forces Obtained from Low-Aspect-Ratio Theory.** Pao-Tan Hsu, John R. Martuccelli, and Holt Ashley. *MIT ASRL TR 52–4*, Dec. 1, 1955. 94 pp. 13 refs.

Preliminary Study of Some Factors Which Affect the Stall-Flutter Characteristics of Thin Wings. A. Gerald Rainey. *U.S., NACA TN 3622*, Mar., 1956. 33 pp. 11 refs. Results of an exploratory, analytical, and experimental study, taking into account Mach and Reynolds Numbers, density, aspect ratio, sweepback, structural damping, location of torsion modal line, and concentrated tip weights.

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ACOUSTICS, SOUND, AND NOISE

BOUNDARY-LAYER-INDUCED NOISE IN THE INTERIOR OF AIRCRAFT. H.S. Ribner. (UTIA Rep. 37) CAI Annual Gen. Meeting, Montreal, May 3, 4, 1956, Paper. 32 pp. 17 refs. Calculation of the acoustic effects of the running ripples for an infinite sheet, indicating that supersonically moving ripples radiate strong sound in the form of Mach waves, and subsonically moving ripples radiate no sound. Formulas are derived for the mean square surface pressure and the energy flux obtained for an assumed idealized turbulent pressure spectrum. Results, adapted to provide a tentative estimate of the noise generated at subsonic speeds in a practical fuselage, indicate that the running ripples are almost noise-free, but multiple reflections at the frames and stringers promote standing waves.

ON THE TRANSMISSION THROUGH A FUSELAGE WALL OF BOUNDARY LAYER NOISE. Appendix I - THE RANDOM RADIATION OF A PLANE SURFACE: FOUR LIMITING CASES. Appendix II - THE SIMPLIFICATION OF THE PLATE RESPONSE INTEGRAL. Appendix III - THE EVALUATION OF THE INTEGRAL SCALE. Appendix IV - LENGTHS AND TIME SCALES FOR THICK BOUNDARY LAYERS. G.M. Corcos and H.W. Liepmann. Douglas Rep. SM-19570, Dec., 1955. 51 pp. Investigation of the turbulent boundary layer fluctuations exciting the fuselage skin in lateral vibration, which in turn induces sound inside the fuselage. The following assumptions are introduced: that the boundary layer is locally homogeneous; the fuselage skin is flat, unlined, and free from axial loads; and that the cabin air is bounded only by the vibrating plate such that only outgoing waves are considered. Results show that sound pressure intensity in the fuselage depends on the square of the free stream density and the airplane speed, and, in general, little on boundary layer thickness; also on such structural properties as the plate thickness, the distance between supports, the plate stiffness, and the damping characteristics.

PRELIMINARY FLIGHT SURVEY OF AERODYNAMIC NOISE ON AN AIRPLANE WING. H.R. Mull and J.S. Algranti. US, NACA RM E55K07, Mar. 2, 1956. 8 pp. Results of measurements of airplane-wing aerodynamic noise and boundary-layer profiles, indicating that the ratio of the root-mean-square sound pressure on the surface of the free-stream dynamic pressure decreases linearly with increasing Mach Number up to M = 0.55 and remains nearly constant thereafter to near the limiting Mach Number of the airplane; and that the sound pressure near the limiting Mach Number increases sharply and probably results from local-shock formations on the wing.

STRUCTURE ASYMPTOTIQUE DES ONDES PROGRESSIVES COMPORTANT DES FRONTS RAIDES. J. Brillouin. France, ONERA NT 30, 1956. 44 pp. In French. Study of the structures of waves propagating in still, homogeneous, and isotropic media at a distance from their source or a caustic point, having a moderate amplitude, and governed by the laws of propagation. Derivation of fundamental equations for the relations governing adiabatic waves, including dynamic, continuity, equation of state, and the equation of conservation of energy. Results indicate that, away from the source, the wave shape tends toward the asymptotic, whose profile is characterized by the following properties: a) starting from a depression, the wave becomes one or more I-shaped, equilibrated, and symmetrically successive profiles, whose length, as well as the total wave length, does not vary during the propagation process; and b) starting from a compression, the wave is composed of two N-shaped semi-profiles, the initial compression and the depression-zone. Results further indicate that starting from the source, the wave and the thickness of the rigid fronts increase rapidly with the decrease in intensity of the corresponding shocks.

AERODYNAMICS

AERODYNAMICS AT VERY HIGH ALTITUDES. S.A. Schaaf. Jet Propulsion, Apr., 1956, pp. 247-250. 19 refs. USAF-ONR-sponsored review of investigations carried out in a low density supersonic wind tunnel at the U. of Calif. during the period from 1952-1955. Results are given for total drag on a cone at Mach Numbers 2 and 4 over a range of Reynolds Numbers; thermal characteristics of a series of cones at zero angle of attack are given in terms of the recovery factor and the Nusselt Number; base-pressures on a typical cylinder-cone configuration are presented over a range of Reynolds Numbers; normal forces on a flat plate are determined and presented in terms of a comparison with theoretical calculation based on Lees and Probstein hypersonic interaction theory; and isotherms of the leading edge region are shown for M = 2 and M = 4.

Aerothermodynamics

LAMINAR HEAT TRANSFER OVER BLUNT-NOSED BODIES AT HYPERSONIC FLIGHT SPEEDS. Lester Lees. Jet Propulsion, Apr., 1956, pp. 259-269, 274. 26 refs. Analysis of laminar heat transfer, taking into account the following limiting cases: thermodynamic equilibrium, in which the chemical reaction rates are regarded as "very fast" compared to rates of diffusion across streamlines; and diffusion, as rate-governing, in which the volume recombination rates within the boundary layer are "very slow" compared to diffusion across streamlines. In the first case the nondimensional enthalpy gradient at the surface is represented by the classical zero pressure gradient value, and surface heat transfer rate distribution is obtained directly in terms of the surface pressure distribution; solutions are obtained for an unyawed hemisphere and an unyawed blunt cone capped by a spherical segment. In the second case the diffusion equation is reduced to the same form as the low speed energy equation, except for the Prandtl Number, which is replaced by the Schmidt Number; maximum value of the ratio between heat energy transfered to the surface by diffusion alone and heat conduction alone is given by the ratio of (Prandtl Number/Schmidt Number) 2/3.

EFFECT OF CHEMICAL REACTIONS IN THE BOUNDARY LAYER ON CONVECTIVE HEAT TRANSFER. David Altman and Henry Wise. Jet Propulsion, Apr., 1956, pp. 256-258, 269. Army-sponsored analysis of the relative change in heat transfer rate resulting from chemical reactions in the boundary layer for either turbulent or laminar flow. Derivation of equations for cases where: molecular diffusivity equals thermal diffusivity or where both are less than the turbulent exchange coefficient; reactions catalyzed by surfaces are such that molecular and thermal diffusivity are not equal; and the reaction occurs only in the laminar region, and therefore the turbulent exchange coefficient equals zero.

ON LAMINAR BOUNDARY LAYERS WITH HEAT TRANSFER. W.D. Hayes. Jet Propulsion, Apr., 1956, pp. 270-274. Analysis of laminar boundary layers in a compressible fluid by two methods: the first using the Stewartson-Illingworth transformation to derive an approximate solution for the case of an imperfect gas by fitting an approximate relation to the density profile, and the second using similar solutions in a momentum-integral approach, where the boundary layer thickness is characterized by a single function of distance along the boundary layer, and where displacement, momentum, and boundary layer thickness are expressed in dimensionless forms directly obtainable from similar solutions.

Boundary Layer

EXPLORATORY INVESTIGATION OF BOUNDARY-LAYER TRANSITION ON A HOLLOW CYLINDER AT A MACH NUMBER OF 6.9. Appendix A - THEORETICAL BOUNDARY-LAYER PROFILES. Appendix B - PROBE EFFECTS. M.H. Bertram. US, NACA 3546, May, 1956. 38 pp. 34 refs. Impact pressure surveys to determine the type of boundary layer, and an attempt to correlate the available data on cylinders and flat plates by the use of nondimensional parameters involving the pressure and the leading-edge thickness. Results indicate that: according to data obtained at a Reynolds Number per in. of 0.34×10^6, with a leading edge thickness varying between 0.001 and 0.003 in. around the circumference of the leading edge, in a portion of the nozzle having a small Mach Number variation, the transition Reynolds Number is between 4×10^6 and 6×10^6; when the cylinder protrudes into a region of the nozzle with a considerable negative pressure gradient, the transition Reynolds Number appears to approach 8×10^6 for one set of data; at a Reynolds Number per in. of 0.26×10^6 the transition Reynolds Number varies from 4×10^6 to 4.5×10^6; leading-edge thickness and free-stream Reynolds Number per in. appear to be important considerations for a correlation of results at Mach Numbers ranging from 2.0 to 4.5; and that Reynolds Number, based on leading edge thickness, is a significant parameter to consider in comparisons of flat-plate or hollow-cylinder transition data from various facilities at a given Mach Number.

THE LAMINAR BOUNDARY-LAYER WITH DISTRIBUTED SUCTION ON AN INFINITE YAWED CYLINDER. K.D.P. Sinha. Gt. Brit., ARC CP 214, 1956. 54 pp. 15 refs. BIS, New York. $1.00. Analysis of the spanwise boundary-layer flow with suction distribution, using the case when $U = cx^m$ (when x is the coordinate in the chordwise direction) to find the chordwise velocity distribution at the edge of the boundary layer, and further extended, by using the Hartree transformations, to obtain the spanwise velocity distribution. Solutions are obtained for the case where m = 0, 1, -1/3 for the above method; and where m = -1/3, -1 the Thwaites transformations are used. Results indicate the following: (a) spanwise profiles for a par-

ticular suction coincide approximately, and form a universal system for which the profile m = 0 is the representative one, which is analogous to the zero-suction case, where the exact Blasius profile is the representative of all the spanwise profiles of the same scale; (b) the exact solution, when m = -1, is an asymptotic suction profile; (c) for zero pressure -gradient the two boundary layers are similar; for negative pressure gradients, where m is positive, the chordwise boundary layer is thinner than the spanwise one; and for positive pressure-gradients, where m is negative, the chordwise boundary layer is much thicker than the spanwise layer; (d) separation is purely a phenomenon of the chordwise flow, and spanwise flows show no tendency to separate.

THE EFFECT OF A SMALL LAMINAR SEPARATION BUBBLE ON THE POTENTIAL FLOW PAST AN AEROFOIL. D.G. Hurley. Australia ARL AN148, Oct., 1955. 21 pp. Development of: a method to calculate the effect of a small bump of arbitrary shape located on the surface of an airfoil, on the surface pressure in its vicinity; and a method to solve the problem of finding the shape of the bump when the changes in pressure produced by the bump are known. Includes an analysis of certain experimental results indicating that the changes in pressure distribution associated with a laminar separation bubble agree with those calculated from the effective change in the shape of the airfoil produced by the bubble.

INVESTIGATION OF BOUNDARY-LAYER TRANSITION ON 10° CONE IN LANGLEY 4- BY 4-FOOT SUPERSONIC PRESSURE TUNNEL AT MACH NUMBERS OF 1.41, 1.61, AND 2.01. A.R. Sinclair and K.R. Czarnecki. US, NACA TN 3648, May, 1956. 17 pp. Experimental determination of the transition Reynolds Numbers between 0.8 and 9.5 x 10^6 per ft. Results indicate that: the transition numbers increase with the tunnel stagnation pressure; Mach Number has no effect on the transition number; and the transition point is unsteady and tends to oscillate approximately ± 10% about the mean value of the transition Reynolds Number.

NOUVELLE MÉTHODE APPROCHÉE DE CALCUL DES COUCHES LIMITES LAMINAIRE ET TURBULENTE EN ÉCOULEMENT COMPRESSIBLE. Alfred Walz. France, Min de l'Air PST 309, 1956. 87 pp. 22 refs. In French. Development of a new approximate method for the calculation of laminar and turbulent boundary layers in compressible flow, taking into account the total nature of the motion and of the kinetic energy. Includes an application to the cone surface.

PERFORATED SHEETS AS A POROUS MATERIAL FOR DISTRIBUTED SUCTION AND INJECTION. R.E. Dannenberg, B.J. Gambucci, and J.A. Weiberg. US, NACA TN 3669, Apr., 1956. 27 pp. 12 refs. Measurements of the resistance to air flow of a series of perforated metal sheets having open areas ranging from less than one per cent up to 41 per cent. Results indicate that the permeability of a perforated sheet is governed by its open-area-ratio, and such factors as the number of holes per square inch, the sheet thickness, and the shape of individual holes have little or no effect on permeability. Includes a discussion of methods for producing small holes and for controlling permeability, and a comparison with other porous specimens.

A WIND-TUNNEL INVESTIGATION OF A 0.4-SCALE MODEL OF AN ASSAULT-TRANSPORT AIRPLANE WITH BOUNDARY-LAYER CONTROL APPLIED. M.P. Fink, B.W. Cocke, and Stanley Lipson. US, NACA RM L55G26a, May 7, 1956. 63 pp. Tests to evaluate lift, drag, and lateral and longitudinal stability and control characteristics to aid in the design of a flight installation. Included are: the effects of such variables as flap hinge position, suction slot design, quantity of air handled, nacelle configuration, flap deflection, and propeller operation on the lifting effectiveness of the boundary-layer-control system; and the effect of asymmetric propeller operation and asymmetric boundary-layer-control application in the control tests.

Control Surfaces

THE GEARED ELEVATOR TAB AND TAIL-UNIT STIFFNESS REQUIREMENTS. Appendix I - EFFECT OF MODAL ASSUMPTIONS. Ll. T. Niblett. Gt. Brit., ARC R&M 2848, 1955. 18 pp. BIS, New York. $1.25. Formulation of a criterion for the torsional stiffness of tabs through theoretical investigation of the distortions of a hypothetical, semi-rigid tail-unit under the loads induced during the elevator displacement, with calculations for tabs covering one-third, two-thirds, and the whole elevator span, and for various proportions of tabs and forward aerodynamic balance, obtained by the substitution of the aerodynamic coefficients and modal functions in the derived equations. Results indicate that: comparatively large elevator tip distortions and loss of control effectiveness, which may be caused by a geared tab covering only a part of the elevator span and located at the elevator root, can be reduced by moving the tab to a position further outboard on the elevator; and, although the flexibility of the tab has little effect on the loss of control effectiveness, large flexibility may lead to large tab distortions and elevator hinge moments.

Fluid Mechanics & Aerodynamic Theory

ÉTUDE EXPÉRIMENTALE DES ÉCOULEMENTS GAZEUX. Marie Merle. France, Min. de l'Air PST 308, 1956. 90 pp. 41 refs. In French. Experimental study of the flow of gases, with an evaluation of existing flow visualization techniques. Relative merits of optic and acoustic methods; and application to the field of supersonic aerodynamics, air jets of high velocity, sound waves produced by air jets, and shock waves in tubes. A discussion of results and of means of improvement is included.

SUR LE PROBLÈME DE LA PLAQUE PLANE SEMI-INFINIE EN ÉCOULEMENT VISQUEUX. Roger Bader and Jacqueline Gilles. La Recherche Aéronautique, Jan.-Feb., 1956, pp. 17-22. In French. Study of the problem of semi-infinite plates in viscous flow, with calculations of the boundary-layer thickness using Lagerström, Cole, and Trilling linearization methods, and taking into account Wiener-Hopf integral equations.

ON THE STABILITY OF VORTEX STREETS. U. Domm. Tech. U., Berlin-Charlottenburg, Hermann Föttinger-Inst. Strömungstech. AFOSR TN-56-27, Oct., 1955. 22 pp. 22 refs. Demonstration of the instability of the von Kármán vortex street even in the case of the classical condition $\frac{t}{l} = 0{,}281$, based on the Schmieden and Kochin, and Dolaptschiew and Domm studies, with a comparison to that of Durand, Coddington, and Birkhoff, indicating and spacing a type of vortex streets of lowest instability, which contains the von Kármán vortex street as the element of lowest translation velocity and largest width under equal assumed circulation. Includes a discussion of the influence of friction and compressibility on stability.

FLOW IN A VISCOUS VORTEX. C. Desmond Pengelley. Southwest Res. Inst. Eng. Mech. Dept., Rep. 494C-1 (AFOSR TN 56-126), Mar. 16, 1956. 59 pp. Derivation of equations for velocity, temperature, and pressure distribution in a two-dimensional viscous vortex with a steady state component of radial flow, assuming a small radial velocity, as compared with the tangential component, and neglecting the heat transfer. Equations are applicable only to laminar flow, and are based on the Navier-Stokes equation, the first law of thermodynamics, and the gas laws. Results indicate that, neglecting heat transfer, the action of viscous forces in compressible flow can cause stagnation temperature to fall in the direction of motion. Includes a discussion of qualitative application of results to turbulent flow.

DETERMINATION OF VORTEX PATHS BY SERIES EXPANSION TECHNIQUE WITH APPLICATION TO CRUCIFORM WINGS. Appendix A - WALL-INTERFERENCE CORRECTIONS. A. Y. Alksne. US, NACA TN 3670, Apr., 1956. 40 pp. Calculation of vortex positions behind a slender equal-span cruciform wing at any angle of bank as a function of the distance behind the trailing edge. Comparison of results for a bank angle of 45° with those of a previously derived closed expression, in agreement for a sufficient distance downstream to include most practical missile-tail positions. Includes computation of the interference forces on an equal-span interdigitated cruciform tail behind a slender equal-span cruciform wing for four angles of bank from the vortex positions found by using the series.

ÉCOULEMENT AUTOUR DE POINTES ÉMERGENTES D'ENTRÉES D'AIR SUPERSONIQUES. J. Nicolas. La Recherche Aéronautique, Jan.-Feb., 1956, pp. 23-26. In French. Development of a method for the calculation of supersonic flow aro emerging profiles, taking into account Oswatitch and Mongrolle methods, and using Taylor and Mac equations to determine the conical flow region.

HYPERSONIC STUDIES OF THE LEADING EDGE EFFECT ON THE FLOW OVER A FLAT PLATE. A. G. Hammitt and S. M. Bogdonoff. Jet Propulsion, Apr., 1956, pp. 241-246. 20 refs. USAF-sponsored experimental investigation in the Princeton helium hypersonic wind tunnel, using optical technique to measure the shock shapes and pressure distribution over a wide range of Reynol Numbers and leading edge thicknesses. Results in dicate that two hypersonic fluid dynamic flow phenomena occur in the flow about a semi-infinite plate, one inviscid and the other viscous; thick leading edges at high Mach and Reynolds Numbers give an essentially inviscid flow in which the effect of the leading edge is felt lengthwise for several thousand leading edge thicknesses; and a linear combination of experimental inviscid flow relation and viscous interaction theory correlates with sharper leading edge data.

TRANSONIC FLOW PAST THE TWO-DIMENSIONAL WEDGE WITH DETACHED SHOCK WAVE. I. Akira Takano. J. Japan Soc. Aero. Eng., Feb.-Mar., 1956, pp. 6-12. Analytical solution of the Tricomi equation for the stream function, subject to the boundary conditions prescribed along the axis of symmetry, the wedge surface, the sonic line, and the shock polar in the small disturbance plane, with the system of the linear equations for the unknown coefficients reduced from the boundary conditions along the sonic line and the shock polar. Calculation of the flow patterns in the physical plane uses the hodograph plane. Solutions for the wedge angle and the free stream Mach Number are represented by the transonic similarity parameter only.

ÉTUDE THÉORIQUE DE LA RÉSISTANCE À L'AVANÇEMENT D'UN CORPS DE RÉVOLUTION EFFILÉ ET POINTU MIS INSTANTANEMENT EN MOUVEMENT DANS UN FLUIDE AU REPOS. P. Bévierre and P. Diringer. La Recherche Aéronautique, Jan.-Feb., 1956, pp. 5-10. In French. Theoretical investigation of the resistance of a tapered, sharp-nosed body of revolution instantaneously set in motion in a fluid at rest, based on the Baranoff method of deriving expressions for the case of uniform acceleration and deceleration in the transonic range. Analysis of the applicability of the obtained solution to the general problem of motion using the superposition concept.

CALCULATIONS OF THE RATE OF THERMAL DISSOCIATION OF AIR BEHIND NORMAL SHOCK WAVES AT MACH NUMBERS OF 10, 12, AND 14. G. P. Wood. US, NACA TN 3634, Apr., 1956. 40 pp. 21 refs. Analysis of thermal dissociation between a Mach Number range covering a temperatur range below which little dissociation occurs, and

temperature above which electronic excitation and ionization may occur. Solutions are found for the rate equation which is based on the simple collision theory, and the conservation equation. Results indicate that the distance behind a normal shock wave, required for a moderately large fraction of the oxygen to dissociate, varies widely with Mach Number and density; and that the distance required for a significant portion of the nitrogen to dissociate is greater than the length of any conceivable vehicle at any density and at any Mach Number less than 14.

INFLUENCE OF THE LEADING-EDGE SHOCK WAVE ON THE LAMINAR BOUNDARY LAYER AT HYPERSONIC SPEEDS. Appendix - EXISTENCE OF DISTINCT VISCOUS AND INVISCID FLOW REGIONS. Lester Lees. J. Aero. Sci., June, 1956, pp. 594-600, 612. USAF-Army-supported investigation of the shock-wave heating and vorticity mode for two cases of steady flow over semi-infinite, insulated flat plates, one with a sharp leading edge, and the other with a blunt leading edge. Results indicate that the streamlines entering the boundary layer over a large region of the plate surface have previously crossed the shock wave near the leading edge where the shock wave is strong and highly curved. Therefore, the temperature at the outer edge of the boundary layer is higher than the free-stream temperature, and the vorticity is not zero. Numerical magnitude of the shock-wave influence is appreciable, and, in the case of the blunt leading edge, the slope of the curve of induced pressures plotted against the hypersonic interaction parameter approaches the Hammitt and Bogdonoff experimental data.

TABLES POUR LA DETERMINATION DES ONDES DE CHOC DETACHEES. H. Cabannes. La Recherche Aéronautique, Jan.-Feb., 1956, pp. 11-16. In French. Development of a method to determine detached shock waves near a body of revolution in uniform supersonic flow parallel to the axis of revolution at M = 2. Calculations using a polynomial consisting of first 16 terms and replacing the double series representing the flow function.

ON SUPERSONIC ROTATIONAL FLOW BEHIND STRONG SHOCK WAVES. I - FLOW PAST AIRFOILS. Abraham Kogan. Technion Res. Devel. Found., Haifa, TN (AFOSR TN-56-165), 1956. 58 pp. 17 refs. Development of a method of successive approximations to the ideal flow past airfoils at high supersonic Mach Numbers, based on the Crocco stream function concept, and taking into account the Lin and Shen results. Application of the method to the treatment of the two-dimensional flow in the leading edge region, in order to evaluate successive derivatives of the shock-wave profile slope and of the surface pressure.

Internal Flow

ANALYSIS OF GAS FLOW SYSTEMS FOR DYNAMIC CONTROL PURPOSES. Appendix I - COMPRESSIBLE FLOW THROUGH A CONTROL VALVE Appendix II - DETERMINATION OF THE TRANSFER FUNCTION OF A TYPICAL GAS FLOW SYSTEM. Appendix III - NUMERICAL CALCULATION OF THE RESPONSE OF A SIMPLE SYSTEM. W.K. McGregor, Jr., D.W. Russell, R.W. Messick, and L.F. Burns. USAF AEDC TR-55-11, Apr., 1956. 60 pp. Development of equations for the prediction of frequency and indicial response of gas flow systems for both a lumped and a distributed parameters. Small perturbation theory is used to determine coefficients of the differential equations, and methods of operational calculus are employed to solve equations for the case of sinusoidal and indicial forcings.

ANALYSIS OF REYNOLDS NUMBER EFFECTS IN FLUID FLOW THROUGH TWO-DIMENSIONAL CASCADES. D.J.K. Stuart. Gt. Brit., ARC R&M 2920, 1955. 39 pp. 16 refs. BIS, New York. $2.40. Approximate mathematical investigation, with detailed study of the laminar and turbulent boundary layer separation as sources of low efficiency. The tests were carried out in conjunction with, and supported by, the results of an extensive testing program in the Cambridge U. Eng. Lab. low-speed wind tunnel. Results indicate that: the pattern of flow through diffusing cascades undergoes considerable change with variation of Reynolds Number, determined by the potential-flow pressure distribution form, with laminar separation occurring at low Reynolds Number and causing rapid loss, and with turbulent separation producing increased loss at higher speeds; theoretical methods can be used to derive the most suitable form for the distribution for given conditions of lift and Reynolds Number, the most satisfactory general form having, on the suction surface, a well-defined suction peak close to the leading edge with a gradually decreasing pressure gradient towards the trailing edge; the precise methods of design outlined yield considerable reduction in the allowed working range of incidence, obviating the need to anticipate large changes in the pressure distribution due to change of incidence. Results also show that: good correlation of three-dimensional effects with the true two-dimensional case can be obtained by the use of corrections outlined; circulation may be estimated accurately from the Joukowski condition through the use of a normally small trailing-edge radius, unless boundary-layer calculations indicate the imminence of laminar or turbulent layer separation; and some method of transition prediction is necessary for full use of theoretical design methods owing to the importance of this phenomenon in determining cascade performance over the whole speed range.

FLAT PLATE CASCADES AT SUPERSONIC SPEED. Rashad M. El Badrawy. (ETH Inst. für Aerodynamik, Zurich, Mitteil. No. 19, 1952.) US, NACA TM 1369, May, 1956. 130 pp. Translation. Analysis which includes calculations of lift and drag coefficients for the flat plate at Mach Numbers ranging from 1.2 to 10 and at different angles of incidence, taking into account the exact flow over both sides of the plate. Calculation of the same coefficients under the assumption of linearized

flow over the plate, according to the Ackeret theory. Derivation of an analytical solution of the problem of interaction between shock waves and expansion waves, and development of a method to determine the lift and drag coefficients for a cascade of flat plates. Analysis of the nonstationary flow in the cascade illustrates the forces acting on the plates during the transition period, under the assumption that the flow through the cascade of flat plates undergoes a small change in the angle of incidence.

FLOW OF GAS THROUGH TURBINE LATTICES. M.E. Deich. US, NACA TM 1393, May, 1956. 136 pp. 23 refs. (Translation of chapter 7 of Tekhnicheskaia Gazodinamika; Moscow, Gosenergoizdat, 1953.) Study of the fluid mechanics of turbine cascades, with fundamental characteristics of lattices and of the flow through lattices, applying the Joukowsky theorem. Includes: electro-hydrodynamic analogy; forces acting on an airfoil in a lattice; friction and edge losses in plane lattice at subsonic velocities; profile losses in lattices at large subsonic velocities; flow of a gas through reaction lattices at supersonic pressure drops; impulse lattices in supersonic flow; and losses in lattices at near sonic and supersonic velocities. Also includes: theoretical methods of investigation of plane potential flow of incompressible fluid through a lattice; several results of experimental investigations of plane lattices at small subsonic velocities; and computation of angle of deflection of flow in overhang section of a reaction lattice at supersonic pressure drops.

STRÖMUNG VOR EINEM ÜBERSCHALL-LAUFRAD. H. Söhngen. DVL Bericht 11, Dec., 1955. 23 pp. Experimental investigation of the flow directed axially at supersonic velocity through a supersonic axial compressor consisting only of a rotor, taking into account the reflections of the turbulence caused by the rotating grids. Results indicate that the turbulence is compensated by the reflected portion which leaves only a completely homogeneous axial flow whose magnitude depends on the angle of incidence of the blades and of the velocity of revolution of the grid; and that in the region behind the rotor the flow is strongly nonhomogeneous and subject to losses.

SOME EFFECTS OF GUIDE-VANE TURNING AND STATORS ON THE ROTATING STALL CHARACTERISTICS OF A HIGH HUB-TIP RATIO SINGLE-STAGE COMPRESSOR. E.L. Costilow and M.C. Huppert. US, NACA TN 3711, Apr., 1956. 52 pp. 15 refs. Experimental investigation using a constant-temperature hot-wire anemometer system to measure flow fluctuations, and a calibrated inductance-type pressure pickup installed in the compressor casing to measure pressure fluctuation, with guide vanes having turning angles of -22.5°, 0°, 22.5°, and 40°, and the stage hub-tip ratio of 0.9. Results indicate that: the initial rotating stall point, number of stall zones formed, and stall propagation rate of a configuration depend upon the overall characteristics of the multi-blade row unit as well as upon blade-row inlet angle and pressure characteristic; the addition of stators to a particular guide-vane-rotor configuration generally increases the flow coefficient where rotating stall was initially encountered, and lowers the stall propagation rate; and the number of stall zones formed in the annulus appears to be independent of guide-vane turning or the presence of stators.

DISCHARGE COEFFICIENTS FOR COMBUSTOR-LINER AIR-ENTRY HOLES. I - CIRCULAR HOLES WITH PARALLEL FLOW. R.T. Dittrich and C.C. Graves. US, NACA TN 3663, Apr., 1956. 39 pp. 10 refs. Experimental investigation to determine the effects of various geometric and flow factors on the discharge coefficients, including hole diameter, wall thickness at the hole, parallel-flow duct height, boundary-layer thickness, parallel-flow velocity, static-pressure level, and pressure ratio across the test hole. Correlation of discharge coefficients corrected for pressure-ratio effects, with a flow parameter incorporating the total and static pressures of the discharge jet and of the parallel-flow stream. Results indicate that the effects of hole diameter and wall thickness at the hole on discharge coefficients are small compared with the effects of parallel-flow velocity and static-pressure ratio across the hole. The effects of duct height, boundary-layer thickness, and static-pressure level are negligible.

LUFTSTRÖMUNGEN MIT DRALL IM KREISROHR HINTER RADIALEM LEITAPPARAT. W. Schiebele. Max-Planck-Inst. für Strömungsforschung, Mitteil. No. 12, 1955. 101 pp. 16 refs. In German. Study of the problem of rotating flow through a cylindrical tube, with a determination of the velocity distribution from pressure, angle, and temperature measurements. Includes a detailed analysis of the flow shape behind twisted and untwisted nozzle blades and of the mixing process occurring during the confluence of two different coaxial rotating flows.

Performance

ANALYSIS OF A ROLLING PULL-OUT MANEUVER. W.J. Oakes, Jr., and P.T. Holliday. J. Aero. Sci., June, 1956, pp. 517-529. 11 refs. Evaluation of four methods to predict the vertical tail angle of attack and the corresponding load, with numerical solutions for three airplane configurations including the straight-, swept-, and delta-wings, in order to define more precisely the attitudes of the airplane. Methods include: the Kelley simplified equation for vertical tail load; the assumption that the sideslip angle equals the angle of attack; a solution of the equations of motion in which the angle of attack is held constant; and a linearized solution of the equations of motion. Results indicate that: the accuracy of the vertical tail loads obtained from the constant angle of attack analysis are comparable to current structural design practice, with the solution indicating that the loss is directional dynamic stability while rolling, caused by the nonlinear inertial forces combining with the unstable tendency of the aerodynamic derivatives in the transonic Mach Number region, may lead to high sideslip angles in the unstable region; measure-

ments are obtained by the application of the simplified analytical methods; and the linearized equations fail to indicate the loss in directional dynamic stability at transonic Mach Numbers and high altitudes due to nonlinear inertial forces.

Stability & Control

ANALYSIS OF A SPIN AND RECOVERY FROM TIME HISTORIES OF ATTITUDES AND VELOCITIES AS DETERMINED FOR A DYNAMIC MODEL OF A CONTEMPORARY FIGHTER AIRPLANE IN THE FREE-SPINNING TUNNEL. S.H. Scher. US, NACA TN 3611, Apr., 1956. 54 pp. Description of a method using film taken by two simultaneously operating motion-picture cameras and of the camera setups and associated equipment. The procedure entails the plotting of attitudes and velocities with respect to airplane body axes, the earth, the relative wind, and the axis of the resultant rotary motion. Results of the investigation indicate that: the oscillatory motion of the spin is not completely regular inasmuch as the period and amplitude of any one cycle of the time-history curves are not exactly the same as those for the preceding and following cycles; oscillations increase after rudder reversal, particularly in the angles of wing tilt and sideslip, with the recovery completed about 1 1/2 turns after rudder reversal; and a relatively high inward sideslip reached during the oscillations is apparently the primary cause of a sudden large decrease in rolling velocity, causing a corresponding large decrease in the gyrodynamic pitching moment, which is holding the model in a nose-up spinning attitude.

SOME EFFECTS OF FUSELAGE FLEXIBILITY ON LONGITUDINAL STABILITY AND CONTROL. Appendix A - CALCULATION OF POTENTIAL STRAIN ENERGY. Appendix B - DERIVATIONS OF TAIL AND WING ANGLES OF ATTACK. Appendix C - DERIVATION OF GENERALIZED MASSES. Appendix D - EQUATIONS FOR EVALUATING THE AERODYNAMIC PARAMETERS. B.B. Klawans and H.I. Johnson. US, NACA TN 3543, Apr., 1956. 42 pp. Theoretical investigation using semirigid analytical technique, with results, obtained through the study of the period and damping of the short-period longitudinal modes of oscillation, of the longitudinal stability margins and the elevator-control deflections required for balance in straight or steady maneuvering flight, indicating that: future designs may incorporate more flexible fuselages and still have longitudinal characteristics approximately equal to those predicted by quasi-static theory and roughly equivalent to those predicted by rigid-body theory; the aerodynamic restoring forces acting on the airplane are sufficient to increase the frequency of the fuselage oscillatory mode in flight, so that it is always higher than either the fuselage ground structural or the airplane-stability natural frequency; and a means, other than elevator or horizontal tail deflection, of longitudinal balance in steady maneuvering flight is necessary at low altitude and high speed with airplanes having fuselage natural frequencies much below those of current designs.

Wings & Airfoils

ÄQUIVALENZSATZ, ÄHNLICHKEITSSÄTZE FÜR SCHALLNAHE GESCHWINDIGKEITEN UND WIDERSTAND NICHT ANGESTELLTER KÖRPER KLEINER SPANNWEITE. Friedrich Keune and Klaus Oswatitsch. ZAMP, Jan. 25, 1956, pp. 40-63. 11 refs. In German. Analysis of the velocity disturbance on low aspect ratio wings in transonic flow which can be reduced to the velocity disturbance on bodies of revolution with the same distribution of cross-sectional area. Includes: similarity laws for low aspect ratio wings obtained by the corresponding similarity law for bodies of revolution; the law of equivalence for the pressure drag for bodies of revolution and pointed low aspect ratio wings with any cross-section at the end, if the end is at a sufficient distance in the supersonic flow; and a generalization, for transonic flow, of the Ward formula, applicable to linearized supersonic equations only.

THE CALCULATION OF THE LOADING AND PRESSURE DISTRIBUTION ON CRANKED WINGS. G.G. Brebner. Gt. Brit., ARC R&M 2947, 1955. 31 pp. 20 refs. BIS, New York. $1.80. Derivation of approximate formulas, which can be extended to the subcritical compressible flow by considering the "analogous wing," using distributions of vortices and sources over the airfoil surface. Includes a comparison of calculations for incompressible flow with experimental results on two wings and with calculations for wings of M, W, and Λ plan form, using a different method.

AN ANALYSIS OF ESTIMATED AND EXPERIMENTAL TRANSONIC DOWNWASH CHARACTERISTICS AS AFFECTED BY PLAN FORM AND THICKNESS FOR WING AND WING-FUSELAGE CONFIGURATIONS. Joseph Weil, G.S. Campbell, and M.S. Diederich. US, NACA TN 3628, Apr., 1956. 92 pp. 29 refs. Summary of data obtained from eleven transonic-bump investigations over a Mach Number range of 0.6 to 1.1, comparing experimental results with those of theoretical calculations for subsonic and supersonic Mach Numbers. At transonic speeds the results indicate that the thin wings generally show smooth downwash characteristics without important consistent effects of sweep angle, aspect ratio, taper ratio, or tail height on the variation of the rate of change of downwash slope with Mach Number in the low lift range; that the use of wings having thickness large enough to produce erratic variations of lift slope, probably will produce similar erratic variations on downwash characteristics; and that the addition of the fuselage to the isolated wing has a greater effect on the absolute magnitude of downwash slope than on its variation with Mach Number. At subsonic speeds, theoretical results for a tail position considerably above the wake centerline, under the assumption of either a flat or a

rolled-up vortex sheet, give an acceptable correlation with those experimentally obtained.

MEASUREMENT OF LIFT, PITCHING MOMENT AND HINGE MOMENT ON A TWO-DIMENSIONAL CAMBERED AEROFOIL TO ASSIST THE ESTIMATION OF CAMBER DERIVATIVES. H.C. Garner and A.S. Batson. Gt. Brit., ARC R&M 2946, 1955. 34 pp. 10 refs. BIS, New York. $2.00. Experimental investigation, with emphasis on the effect of boundary-layer transition, using a two-dimensional RAE 102 airfoil with four per cent parabolic centerline and plain control surfaces of chord ratios 0.2 and 0.4 at 0.95×10^6 Reynolds Number. Includes aerodynamic coefficients obtained from measured forces and moments and from pressure distribution at one section, with a suggested new formula for the hinge-moment derivative, corresponding to an aerodynamic camber as it normally operates on a lifting surface in incompressible viscous flow.

OPTIMUM THICKNESS AND LIFT DISTRIBUTION FOR A FUSELAGE IN THE PRESENCE OF A PRESCRIBED WING SYSTEM. M.E. Graham. Douglas Rep. SM-19615 (Revised), Mar., 1956. 8 pp. 11 refs. Derivation of a generalized "area rule," using the Hayes drag formula, expressed in terms of sources, lift singularities, and side force singularities. Two simple examples illustrate that optimum fuselage singularity distributions are obtained if the intensity of fuselage singularity plus a lineal distribution consist of the optimum source distribution, the optimum lift distribution, and the optimum side force distribution. This derivation is applicable to such configurations as high-wing monoplanes and ring wings.

A FIRST-ORDER FORMULATION OF THE UNSTEADY SUPERSONIC FLOW PROBLEM FOR FINITE WINGS. J.W. Miles. J. Aero. Sci., June, 1956, pp. 578-582. Reduction to two steady flow problems of the determination of the pressure distribution over a thin finite wing in supersonic flow, owing to a prescribed incidence which varies slowly in time. The first is the steady flow problem for the given plan form with modified incidence; the second corresponds to a modified steady flow problem in which the wake is neglected and the potential is required to vanish along the subsonic trailing edges.

THEORETICAL PRESSURE DISTRIBUTIONS FOR SOME SLENDER WING-BODY COMBINATIONS AT ZERO LIFT. P.F. Byrd. US, NACA TN 3674, Apr., 1956. 39 pp. 13 refs. Calculation of the pressure distribution for both subsonic and supersonic speeds on slender, swept wings alone, with constant chord and tip, and on combinations, where the wing is mounted on a circular cylinder, or combined with a body indented such that the axial variation of cross-sectional area of the combination is constant. Included are the effects of Mach Number and sweep angle. Results, presented in graphical form, indicate that: the pressure coefficients have a finite negative value at the leading edge and increase to finite positive values at the trailing edge, for the region adjacent to the body the pattern of the isobars is qualitatively similar to the case for the wing alone, but with lower pressures; and for the indented combination the pressures are essentially two-dimensional over the whole wing, and tend to diminish the maximum perturbation velocity along the wing.

AEROELASTICITY

MEASUREMENT OF AERODYNAMIC FORCES FOR VARIOUS MEAN ANGLES OF ATTACK ON AN AIRFOIL OSCILLATING IN PITCH AND ON TWO FINITE-SPAN WINGS OSCILLATING IN BENDING WITH EMPHASIS ON DAMPING IN THE STALL. A.G. Rainey. US, NACA TN 3643, May, 1956. 66 pp. 18 refs. Results of an experimental investigation indicating that: the magnitude of oscillatory normal-force and pitching-moment coefficients for a two-dimensional wing oscillating in pitch about the midchord at high mean angles of attack are much larger at some conditions than at low mean angles of attack; large regions of angle of attack and reduced frequency exist wherein a single-degree-of-freedom torsion flutter is possible because of unstable aerodynamic-damping moments for pitching oscillations; the effect of increasing Mach Number from 0.35 to 0.7 causes a decrease in the initial angle of attack at which unstable damping occurs; and the aerodynamic damping for bending oscillations is generally higher at high angles of attack than at low angles of attack, and no unstable damping is encountered over the range of configurations, angle of attack, and reduced frequency covered by these experiments.

AEROELASTIC PROBLEMS OF LOW ASPECT RATIO WINGS. III - AERODYNAMIC FORCES ON AN OSCILLATING DELTA WING. J. Leyds. Aircraft Eng., Apr., 1956, pp. 119-122. 11 refs. Analysis of flutter of a delta wing in supersonic and subsonic flow to determine lift and moment coefficients at any station of the wing, taking into account spanwise and chordwise bending and rotation. Includes calculations of natural modes of vibration of the wing based on Scanlan and Rosenbaum methods and a comparison between British and American techniques.

FLUTTER PREDICTION IN PRACTICE. E.G. Broadbent. Gt. Brit., RAE TN Struc. 185, Feb., 1956. 32 pp. Summary of available theoretical and experimental resources, and a description of specific investigations for four different cases: the combined effect of two tabs; elevator flutter followed by flight flutter tests; aileron flutter at high subsonic Mach Number; and rudder flutter at high subsonic Mach Number. Results indicate that: the main broad trend in flutter prediction is the correlation to a steadily increasing degree between calculations and measurements; control surfaces on transonic and supersonic power-controlled aircraft should be designed without massbalance and oper-

ated from two or more spanwise positions; backlash should be kept to a minimum and the dynamic stiffness as high as possible; and a damper installation should be designed as an emergency precaution in case of flutter in a single degree of freedom.

FREE VIBRATIONS AND BUCKLING OF A RECTANGULAR PLATE WITH DISCONTINUOUS BOUNDARY CONDITIONS. W. Nowacki. Bul. Acad. Polonaise Sci. (Warsaw), No. 4, 1955, pp. 159-167. Study of the cases in which only one of the edges is subjected to discontinuous conditions, leading to the development of an approximation method applicable to cases in which these conditions prevail on more than one edge, with two numerical examples: one for the case of free vibrations of the plate in the absence of compressive forces; and the other for the case taking buckling into consideration Proceding from the derivation of integral equations for a plate with continuous conditions on three of its edges and different conditions on each of two segments of the fourth edge, an approximate solution is worked out by replacing the integral by a sum, from which the determinant yields a transcendental equation to determine the frequency of the free vibrations or the critical force. Included in the development are considerations of a plate firmly fixed along one segment and free along the other of the fourth edge, and of a plate freely supported along its entire circumference with a slit of one of the segments of the fourth edge placed on its axis of symmetry.

FATIGUE LOADINGS IN FLIGHT: LOADS IN THE TAILPLANE AND FIN OF A VARSITY. Anne Burns. Gt. Brit., RAE TN Struc. 183, Jan., 1956, 20 pp. Experimental data for conditions including turbulence, take-off, landing, taxiing, and ground running of the engines, with measurements obtained by means of electrical resistance strain gages and continuous recording equipment, and accelerations recorded at the aircraft c.g. to determine the relationship of the tail and fin loads to the c.g. accelerations, and hence to the gust velocities. Results indicate that: for the tailplane the ground buffeting loads are likely to be more important than the loads in turbulence; in taxiing and landing the tailplane loads are relatively insignificant; for the fin the loads in turbulence are predominant; and that tailplane loads can be related empirically to vertical gust velocities so that statistical information on gust occurrences can be used to estimate tailplane load occurrences, but that fin loads and gust velocities appear to be less simply related.

DAS STABILITATSVERHALTEN DER NICHTLINEAREN BIEGESCHWINGUNGEN DES AXIAL PULSIERREND BELASTETEN STABES. F. Weidenhammer. Ing.-Arch., No. 1, 1956, pp. 53-68. 14 refs. Study of nonlinear vibrations in rods subjected to loading and having zero moment, using the fluctuating phase and amplitude method. The resonance curve for londitudinally induced transversal vibrations is calculated, taking into account the damping forces, and using Haag theory.

ON PANEL FLUTTER AND DIVERGENCE OF INFINITELY LONG UNSTIFFENED AND RING-STIFFENED THIN-WALLED CIRCULAR CYLINDERS. Appendix A - STEADY LINEARIZED FLOW PAST A STATIONARY DEFORMED CYLINDER. Appendix B - AIR FORCES ON A CYLINDER IN DIVERGENT OSCILLATION. Appendix C - EQUILIBRIUM OF UNSTIFFENED CYLINDER - FLÜGGE'S EQUATION. Appendix D - IMPORTANCE OF DAMPING IN UNSTIFFENED CYLINDER. R.W. Leonard and J.M. Hedgepeth. US, NACA TN 3638, Apr., 1956. 52 pp. 16 refs. Theoretical investigation of aeroelastic stability of thin-walled cylindrical missile bodies or other aircraft components using thin, curved panels, applying the Donnell cylinder theory in conjunction with the linearized unsteady potential-flow theory to obtain equilibrium equations for panel flutter, and a Nyquist diagram technique to derive analytical criteria for the location of stability boundaries. Results indicate the following: for unstiffened cylinders with vanishingly small structural damping, the only possible instability at subsonic Mach Numbers is static divergence; in supersonic flow flutter occurs in thin cylinders in the form of a traveling wave whose propagation velocity is the velocity of the external flow minus the speed of sound. Relatively large ratios of cylinder-wall thickness to radius are necessary for stability; and the addition of an internal fluid has a destabilizing effect on the unstiffened cylinder. For a ring-stiffened cylinder the flutter is not possible at subsonic Mach Numbers, and only very small thickness ratios are required to prevent divergence.

WIND-TUNNEL TESTS ON THE SYMMETRIC AND ANTISYMMETRIC FLUTTER OF SWEPT-BACK WINGS. D.R. Gaukroger. Gt. Brit., ARC R&M 2911, 1955. 21 pp. BIS, New York. $1.40. Experimental investigation taking into account wing sweepback, the position of the wing and fuselage center of gravity, fuselage mass, fuselage pitching and rolling moments of inertia, and tailplane volume coefficient. Results indicate that flutter speeds, lower than the flutter speed of the wing with the root rigidly fixed, may be obtained for a tailless aircraft with slight sweepback under unfavorable inertia conditions of the fuselage; for other sweepback and inertia conditions the flutter speeds are likely to be equal to, or higher than, the fixed root speeds.

MODELS FOR AERO-ELASTIC INVESTIGATIONS. H. Templeton. Gt. Brit., RAE TN Struc. 179, Nov., 1955. 22 pp. Derivation of scale relationships for the design of prediction models, based on flutter equations having nondimensional square matrices of inertia, aerodynamic damping, aerodynamic stiffness, and structural stiffness coefficients, including flexible skin, segmental airfoil, stressed skin, solid, and semi-rigid types.

BESTIMMUNG VON RAHMENSCHWINGUNGEN MIT HILFE DES MATRIZENKALKÜLS. H. Fuhrke. Ing.-Arch., No. 1, 1956, pp. 27-42. In German. Development of matrices for longitudinal and tor-

sional vibrations used to study the coupling of transversal and longitudinal vibrations and of transversal and torsional vibrations. Includes a formulation of boundary conditions for truss angles and of eigenvalue equations for closed or open trusses.

AIRPLANE DESIGN

Landing Gear

LOW-SPEED YAWED-ROLLING CHARACTERISTICS AND OTHER ELASTIC PROPERTIES OF A PAIR OF 26-INCH-DIAMETER, 12-PLY-RATING, TYPE VII AIRCRAFT TIRES. Appendix - INTERPRETATION OF RESULTS OF DYNAMIC LATERAL-ELASTICITY TESTS. W.B. Horne, R.F. Smiley, and B.H. Stephenson. US, NACA TN 3604, May, 1956. 98 pp. Determination of low-speed cornering characteristics under straight yawed rolling over a range of inflation pressures and yaw angles for two vertical loads. Cornering characteristics of one tire rolling along circular paths of different radii are investigated for one condition of vertical load and internal pressure. Static tests are performed to determine vertical, lateral, torsional, and fore-and-aft elastic characteristics of the tires, and vibrational tests to determine such dynamic elastic characteristics as: lateral force, drag force, torsional moment, pneumatic caster, vertical tire deflection, lateral tire deflection, wheel torsion or yaw-angle, rolling radius, and relaxation length.

Windshields

DEVELOPMENT OF A ONE-PIECE PLASTIC WINDSHIELD FOR HIGH-SPEED AIRCRAFT. R.D. Huff, S.C. Patrick, and C.R. Frownfelter. USAF WADC TN 55-241, Pt. I, June, 1955. 72 pp. 21 refs. Studies of materials, loads, temperatures, and stresses for both single- and double-wall windshields; includes an investigation of temperature gradients and thermal stresses corresponding to a diving flight path. Results indicate as a critical design condition the buckling of the windshield panels caused by thermal gradient stresses, high windshield temperatures, and the positive aerodynamic loads. Optical tests on laminated plastics indicate the difficulty of satisfying the distortion specifications. Includes preliminary design drawings for single-wall and double-wall windshields.

AIRPLANE PERFORMANCE

AN INVESTIGATION OF HIGH ALTITUDE CRUISING CONDITIONS FOR TURBO-JET AIRCRAFT. R.T. Shields, J. Stephenson, and I.E. Utting. Gt. Brit., ARC CP 215, 1956. 40 pp. BIS, New York. $0.75. Experimental investigation using the Ashton, a nontypical research vehicle for which maximum specific air range is achieved at a Mach Number below the drag critical value, in order to experience techniques of specific air range measurement at the low equivalent air speeds required for optimum range, to determine handling problems arising in the application of "climb cruise" techniques for long cruising flights near the minimum drag speed, and to gather evidence on any scale effects on specific air range. Other investigative techniques used include stabilized level speed and quasi-level tests. Results indicate that: generally, apart from difficulties arising from backlash in the elevator trimmer circuit and some that might be encountered in aircraft with low static longitudinal stability due to high static margins, long range flights in the Ashton using the "climb cruise" technique are practicable with manual control; conditions for obtaining maximum specific air range agree with those predicted by theory; a change of 10° C. in air temperature results in a change of 1 3/4 per cent in maximum specific air range, with the increase in temperature producing reduced range; performance measurements at speeds less than about M = 1.2 should be obtained by quasi-level tests; and that, owing to scale effects on engine performance and aircraft drag, the "nondimensional" specific air range falls by the order of 5-8 per cent during a range flight, with the corresponding weight ratio about 0.8, suggesting that the effect is likely to be greater for a long range bomber with a greater proportional disposable load and consequent greater height increase during a sortie.

COMPUTERS

SUR UN NOUVEL ANALYSEUR ANALOGIQUE DE RÉGIMES TRANSITOIRES; APPLICATION À L'ÉTUDE DE CERTAINS PHÉNOMÈNES DE RÉGIME VARIABLE. J. Miroux. France, ONERA Pub. 81, 1955. 90 pp. 63 refs. In French. Development of an analog analyzer incorporating networks of small resistance and capacity, enabling the signals to be repeated periodically, registered with minimum error, easily transformable, and of easy access. Includes: a description of the apparatus in terms of size, weight, control, and verification; a study of thermal shocks and viscous elasticity; and application to the study of certain phenomena of variable regime.

FUELS AND LUBRICANTS

ÉTUDE DE LA LUBRIFICATION SOUS PRESSION RAPIDEMENT VARIABLE; CAS DES LUBRIFIANTS PLASTIQUES; EXISTENCE DE LEUR ANISOTROPIE. Fernand Charron. France, Min. de l'Air PST 310, 1956. 27 pp. In French. Study of the lubrication under rapidly variable pressure in tubes or between the surface of two disks, using special recording apparatus to compare the properties of plastic lubricants between them and with those of liquids of various viscosities. Includes an analysis of the optical anisotropy of plastic specimens.

INSTRUMENTS

Flight Instruments

WIND-TUNNEL INVESTIGATION OF A NUMBER OF TOTAL-PRESSURE TUBES AT HIGH ANGLES

OF ATTACK; SUBSONIC, TRANSONIC, AND SUPERSONIC SPEEDS. William Gracey. US, NACA TN 3641, May, 1956. 30 pp. 12 refs. Results of experiments in five Langley Aero. Lab. wind tunnels indicate that the configurations of the various tubes depend on the external shape, internal shape, and the type of total-pressure entry. External shapes tested include cylindrical, conical, and ogival nose sections. Internal shapes and total-pressure entries are varied on the basis of such factors as size of impact openings, internal chamber shape, leading-edge slant profile, and shielding.

Gyroscopes

THE FLOATING INTEGRATING GYRO AND ITS APPLICATION TO GEOMETRICAL STABILIZATION PROBLEMS ON MOVING BASES. C.S. Draper, W. Wrigley, and L.R. Grohe. Aero. Eng. Rev., June, 1956, pp. 46-62. 33 refs. Review of geometrical stabilization systems, and description of gyro units used in such systems, with emphasis on gyro units capable of sensing angular deviation of a reference member from a reference orientation, and of receiving input signals commanding charges in reference orientation. Includes a discussion of performance characteristics of typical units, and a method of testing gyro units of various types.

Tachometers

AN AIRBORNE RECORDING TACHOMETER USING THYRATRONS. F. Walder. Gt. Brit., AAEE Rep. Res/292, Feb. 6, 1956. 9 pp. Development of a galvanometer camera recorder to measure rotor speed to an accuracy of ± 1%. Input from an a.c. tachometer generator is passed through a thyratron valve relay operating at a frequency proportional to the rotor speed, which in turn charges a capacitor. The circuit is not sensitive to generator voltage. Discharge from the capacitor is measured by a germanium diode and a metering circuit which measures average rectified diode current.

Temperature Measuring Devices

A SONIC-FLOW ORIFICE PROBE FOR THE IN-FLIGHT MEASUREMENT OF TEMPERATURE PROFILES OF A JET ENGINE EXHAUST WITH AFTERBURNING. C.D. Havill and L. S. Rolls. US, NACA TN 3714, May, 1956. 18 pp. Description of a temperature measuring system using two sonic-flow orifices in series, and mounted in a swinging pitot-static probe. The system has only a small variation in temperature at the thermocouple, and the temperature change is measured as a change in pressure. A static calibration of the probe in a controlled furnace indicates that there is a ±10.5° F. standard deviation of the errors and a characteristic time lag of 0.045 sec.

MATERIALS

INVESTIGATION OF THE COMPRESSIVE STRENGTH AND CREEP LIFETIME OF 2024-T ALUMINUM-ALLOY SKIN-STRINGER PANELS AT ELEVATED TEMPERATURES. E.E. Mathauser and W.D. Daveikis. US, NACA TN 3647, May, 1956. 29 pp. Includes: comparison of results theoretically predicted and experimentally obtained at room temperature and at 400° F; creep lifetime curves for four values of slenderness ratio; discussion of creep characteristics; and description of a method using time-dependent compressive stress-strain (isochronous) curves to predict creep lifetime. Results indicate satisfactory agreement between predicted and experimentally determined strengths, and satisfactory theoretical calculation of average stress against unit shortening curves.

INFLUENCE OF ALLOYING UPON GRAIN-BOUNDARY CREEP. F.N. Rhines, W.E. Bond, and M.A. Kissel. US, NACA TN 3678, Apr., 1956. 16 pp. Measurements of the grain-boundary displacement, occurring in bicrystals during creep at elevated temperatures, as a function of the copper content in a series of aluminum-rich, aluminum-copper, solid-solution alloys. The minimums in stress and temperature, below which grain boundary motion does not occur, increase regularly with the copper content, and the grain-boundary gliding occurs as a complex plastic motion within a layer of metal adjacent to the grains boundary and not as a shear upon an interface.

THE CORROSION RESISTANCE OF BINARY MAGNESIUM-LITHIUM ALLOYS IN SHEET FORM. H.G. Cole. Gt. Brit., RAE TN Met. 235, Feb., 1956. 7 pp. Experimental investigation by total immersion in 3% sodium chloride solution and by intermittent sea water spray, with results applicable to the prediction of probable corrosion behavior of more complex alloys, and to the selection of a cladding alloy when required to protect a stronger but less resistant base core. Results indicate that: binary alloys containing up to 10% lithium by weight have a corrosion resistance approximately equal to that of 1.5% manganese alloy sheet, and are equally well protected by conventional treatment; and corrosion resistance falls rapidly at lithium contents of 12% and over.

MATHEMATICS

ON CURVES OF MINIMAL LENGTH WITH A CONSTRAINT ON AVERAGE CURVATURE, AND WITH PRESCRIBED INITIAL AND TERMINAL POSITIONS AND TANGENTS. L.E. Dubins. Carnegie Inst. Tech. TR 10 (AFOSR-TR-56-12), Apr., 1956. ARDC-supported study of the minimal length path for a particle pursuing a continuously differentiable route from an initial point u to a terminal point v with its respective velocity vectors U and V to prove a theorem implying that for n = 2, an R-geodesic is necessarily a continuously differentiable curve which consists of not more than four pieces, each of which is either a straight line segment or an arc of a circle of radius R. The corollary theorem further implies that four is the least integer for which this is true.

THE ASYMPTOTIC SOLUTION OF LINEAR DIFFERENTIAL EQUATIONS OF THE SECOND ORDER IN A DOMAIN CONTAINING ONE TRANSITION POINT. F.W.J. Olver. Philos. Trans. Royal Soc. (London), Ser. A, Apr. 19, 1956, pp. 65-97. Analysis of the case in which the only transition point in D is simultaneously a single pole of p(z) and a double pole of q(z), indicating that the solutions of differential equations have asymptotic expansions which are uniform with respect to z and similar in character to those of previous calculations, in terms of Bessel functions whose order depends on the behavior of q(z) at the transition point. Application of results to hypergeometric and confluent hypergeometric equations and to the determination of new asymptotic expansions of Legendre, Laguerre, and Coulomb-wave functions of large orders.

MISE EN ÉQUATIONS ET RÉSOLUTION DES RESEAUX ÉLECTRIQUES EN RÉGIME TRANSITOIRE PAR LA MÉTHODE TENSORIELLE. A. Kaufmann. France, Min. de l'Air NT 56, 1955. 104 pp. 108 refs. In French. Extension of the Kron tensor method used for the derivation of equations and for the solution of symmetric and nonsymmetric networks in the general case where initial conditions are not entirely null and to indicate the appearance of tensor structures in the location of meshes and node pairs. Includes an analysis of the Kirchhoff law and Maxwell method.

NONLINEAR VOLTERRA FUNCTIONAL EQUATIONS AND LINEAR PARABOLIC DIFFERENTIAL SYSTEMS. R.H. Cameron. U. Minn. TR 1 (OSR-TN-55-378), Sept. 26, 1955. 64 pp. 18 refs. Analysis to obtain existence theorems applicable to the solution of the equations and to the determination of values for Wiener integrals, and to obtain minimality theorems for the solution of systems. Existence theorems, using the Fagen and Cameron transformations to complete proof, are based on the Darling and Siegert results, which give a closed form solution of an integral equation generalizing n = 1.

MISSILES

HISTORY OF GERMAN GUIDED MISSILES DEVELOPMENT. NATO, AGARD Seminar, Munich, Apr. 23-27, 1956. Of the 28 papers presented at this meeting, which was sponsored by the Wissenschaftliche Gesellschaft für Luftfahrt (WGL), 20 have been issued in preprint form (text only): Summary of German Developments in Guided Missiles, Th. Benecke. Development and Test of the Missile-Borne Control and Stabilization System Used for the V-1, H. Temme. Guidance and Control with Particular Applications to the Henschel-Missiles, H. Wagner. Contributions to the Guidance of Missiles, E. Fischel. Guidance of Surface-to-Air Missiles by Means of Radar, K.H. Schirrmacher. The Solid Propellant Rocket for the Propulsion of Missiles; Their Design and Performance, H. Vüllers. Summary of the Development and Use of Jet Propulsion, O. Lutz. Development of Peroxide Propellant Rockets, H. Walter. Development and Testing of a Drone for Anti-Aircraft-Target Simulation, W. Kloepfer. Guidance System for Air-Surface Missiles, J. Dantscher. Development of Guidance Systems for Air-to-Air Missiles, J. Dantscher. The Control System of the V-2, O. Müller. The Physical and Technical Development of Infra-Red Homing Devices, E.W. Kutzscher. Summary of the Development of High Frequency Homing Devices, G. Güllner. A Guidance System Using Television, F. Münster. Testing of Ram Jets by Firing as Projectiles, Wolf Trommsdorff. Development of the V-1 Pulse Jet, F. Gosslau. Summary of the Development of Proximity Fuses, F. von Rautenfeld. The Development of the V-2 Rocket Engine, M. Schilling. Spoiler Control of Missiles, G. Ernst. The complete proceedings are scheduled to be published later in the year by AGARD. This volume will include figures and discussions.

NUCLEAR ENERGY

SELF SHIELDING IN RECTANGULAR AND CYLINDRICAL GEOMETRIES. Harold Schneider, P.G. Saper, and C.F. Kadow. US, NACA TN 3661, Apr., 1956. 40 pp. Solutions of the flux equations of the steady-state diffusion theory (P_2) and the transport theory (P_3) for multiregion cells of rectangular and cylindrical geometries, representing a given arrangement of moderator, fuel, and cladding, considered to be homogeneous. The three-region cells are of slab geometry and consist of water, steel, and uranium regions. The two-region cells are of identical volumetric proportions and composition, differing only in the homogeneous dispersion of uranium in water. For the dimensions of the equivalent two regions of the cylindrical cell the same homogeneous self-shielding factor of the corresponding cell is maintained. Additional results are calculated considering the effects of the chemical binding in water of the flux distributions and self-shielding factors.

PARACHUTES

DRAG AND STABILITY OF PARACHUTES. H. G. Heinrich. Aero. Eng. Rev., June, 1956, pp. 73 - 81. Theoretical study of several types including: solid flat parachutes with medium porosity, oscillating, gliding, or performing a combined motion; ringslot parachutes with considerably high porosity; ribbon; formed core, characterized by the drawn-in skirt; and the guide surface parachutes, characterized by a conical surface at the lower portion of the canopy. Results indicate that the effective drag of statically unstable parachutes varies strongly with the rate of descent, owing to a dynamic instability caused by insufficient static stability.

PHOTOGRAPHY

FIELD EVALUATION OF ASKANIA CINE-THEODOLITES. I - TEST DESIGN AND RESULTS. Ernest Stern. II - STATISTICAL ANALYSIS. R.J. Nichol. USAF MTC TN-56-18, Apr., 1956. 81 pp. 12 refs. Includes outline of methods to analyze and

reduce data, derived from the use of two "in-close" targets, and examination of several known error sources and their influence on the results, with suggestions for further study and change in operational procedure. Results indicate that: the instruments conform to the design specifications (± 20 in. per angle) for static, photographic reproducibility of angular data; the truly random error is unaffected by the field use of the instrument; the variations in systematic error are adversely affected by prolonged field use; relatively large bias error, unattributable to known sources of bias and only negligibly affected by the most careful use of the level bubbles provided, is present in Askania No. 670; data obtained from the overall system is unaffected by dial eccentricity and lens bend, or by the use of interim night fiducials, and the survey method is applicable and accurate, even at a distance of 100 to 150 feet from the Askania.

PHYSICS

INTRODUCTION À LA MÉCANIQUE DES MILIEUX CONTINUS. Paul Anglès d'Auriac. France, Min. de l'Air PST 306, 1955. 139 pp. In French. Mathematical analysis of the stresses and deformations in isotropic homogeneous media, using the technique of linear transforms and algebraic matrices. Includes a study of linear and two-dimensional elasticity, torsional stresses, and the deformations of liquids for kinematic and static states.

POWER PLANTS

Jet & Turbine

A REVIEW OF SOME COMBUSTION PROBLEMS ASSOCIATED WITH THE AERO GAS TURBINE. J. S. Clarke. J. RAeS, Apr., 1956, pp. 221-237; Discussion, pp. 237-239; Author's reply, pp. 239, 240. 10 refs. Developmental survey in the light of experiences and detailed studies of the burning of atomized sprays, including analyses of: the required combustion chamber operating conditions and progress in chamber design trends; flame stabilization and heat release rate; the comparison between pipe, tubo, and fully annular chambers, and upstream and downstream fuel injection; the development of specific chambers; ignition; and the choice of materials for flame tube operating conditions. General combustion problems covered include: temperature traverse, pressure loss, combustion efficiency, the effect of fuel properties, and carbon formation.

METHOD OF CALCULATING CORE DIMENSIONS OF CROSSFLOW HEAT EXCHANGER WITH PRESCRIBED GAS FLOWS AND INLET AND EXIT STATES. E.R.G. Eckert and A.J. Diaguila. US, NACA TN 3655, Apr., 1956. 25 pp. Description of a calculation procedure based on charts plotted for each surface with prescribed entrance conditions, pressure drops, and temperature changes, yielding the Reynolds Numbers which determine the flow velocities on both sides of the heat exchanger and the three basic dimensions of the core. Includes application of the method to an illustrative example of heat transfer from air to air.

CHOISE OF DESIGN FOR AN ADVANCED TURBOJET. F.H. Keast. CAI Annual Gen. Meeting, Montreal, May 3, 4, 1956, Paper. 20 pp. Analysis of the effect of size and design parameters on engine weight and fuel consumption. Includes a discussion of various compressor and afterburner configurations, and the effects of materials and pressure ratio.

PERFORMANCE CRITERIA OF GAS-TURBINE COMBUSTION CHAMBERS; A METHOD OF COMPARISON AND SELECTION FOR THE DESIGNER. D.B. Spalding. Aircraft Eng., Apr., 1956, pp. 104-110. 12 refs. Expression of the combustion chamber test data by introducing dimensionless performance criteria, plotted for the comparison of various designs. Evaluation of an idealized model for the determination of the effects of changes in overall fuel-to-air ratio, more effective than in the case of assumed homogeneous conditions in the flame-tube.

PERFORMANCE AND OPERATIONAL STUDIES OF A FULL-SCALE JET-ENGINE THRUST REVERSER. R.C. Kohl. US, NACA TN 3665, Apr., 1956. 38 pp. Experimental investigation, with an axial-flow turbojet engine equipped with a hemispherical target thrust reverser and pylon-mounted under the wing of a cargo airplane at both stationary and taxi conditions. Includes measurements of the heat-rise patterns and rates resulting from impingement of the reversed hot gases on a simulated lower wing surface. Results indicate that: the reverse-thrust ratio increases with corrected engine speed and nozzle pressure ratio; the reduction of four to eight percentage points in the reverse-thrust ratio of the full-depth hemisphere obtained during full-scale is attributed, in part, to gas-flow leakage along the parting line of the actuated full-scale target; closing the thrust reverser in the stationary airplane causes reingestion of the reversed hot gases, increasing the engine-inlet temperature; the temperature measured on the lower surface of a simulated wing located 32 1/2 in. above the engine centerline indicates a maximum rise of nearly 400° F, and a maximum rate of rise of 28° F per sec. during reverse-thrust operation; and the truncated version of the basic hemispherical configuration produces a peak thrust reversal of 52 per cent at maximum corrected engine speed and a nozzle pressure ratio of 1.84, approximately five to eight percentage points less than that of the full-depth hemisphere.

Rocket

THEORY OF COMBUSTION INSTABILITY IN LIQUID PROPELLANT ROCKET MOTORS. Luigi Crocco and Sin-I Cheng. (AGARDograph No. 8). London. Published for and on behalf of AGARD, NATO, by Butterworths Scientific Publications; New York, Interscience Publishers, Inc., 1956. 200 pp., illus., diagrs. 37s. 6d. $5.25. Investigation of

the combustion process taking into account time and space lag, chugging or low frequency instability, and screaming or longitudinal high-frequency instability. The analysis of chugging includes equations for the feeding system in both mono-propellant and bipropellant cases considering constant feed-rate and constant pressure rate, and treats the effects of temperature variation due to pressure oscillations, and the effect of servo stabilization. The analysis of screaming includes cases of combustion concentration at the injector end with a short nozzle, combustion at an arbitrary axial location with a short nozzle, combustion with a long nozzle, and the effects of time lag spread; it also presents perturbation equations for arbitrarily distributed combustion; calculations for the burning rate, a solution by iteration for the neutral angular frequency; a solution of the eigenvalue problem for sensitive part of total time lag. Theoretical and experimental results are compared.

STUDIES ON THE REACTION STABILITY OF SOLID PROPELLANT CHARGES. Leon Green, Jr. Appendix - REPORT ON HEAT TRANSFER ANALYSIS IN CONNECTION WITH THE BURNING OF SOLID PROPELLANTS. C.C. Lin and W.E. Gibson. Aerojet-Gen., Rep. 1077 (AFOSR TR-56-10), Mar. 9, 1956. 121 pp. 35 refs. Study of the phenomena of resonant burning, including the mechanism of coupling between the gas-phase oscillations and the rate of solid-phase decomposition by an analysis of the effect of transverse oscillations on the rate of heat transfer to the regressing surface and of the effect of heat-transfer fluctuations on the solid burning rate. Includes: a description of static test firings of experimental propellant charges, using pressure-measuring instrumentation systems of high- and low-frequency response in order to determine the influence of propellant composition and charge configuration on the severity of resonant burning; and a review of previous investigations of the reaction irregularities in solid-propellant rocket motors, indicating that high-frequency pressure oscillations of finite amplitude can prevail in the charge cavity during outwardly stable operation.

ROTATING WING AIRCRAFT

ANALYSIS AND COMPARISON WITH THEORY OF FLOW-FIELD MEASUREMENTS NEAR A LIFTING ROTOR IN THE LANGLEY FULL-SCALE TUNNEL. H.H. Heyson. US, NACA TN 3691, Apr., 1956. 162 pp. 15 refs. Experimental investigation at simulated flight conditions covering tip-speed ratios between 0.095 and 0.232 and calculated wake skew angles between 75.0° and 85.8°, comparing data with theory at those locations for which theoretical calculations are available, in order to determine the validity of the calculations and the general nature of the flow field. Results indicate that: the normal component of induced velocity of a lifting rotor may be calculated with good accuracy by available theory up to three-quarters of a diameter behind the leading edge of the rotor disk, assuming a realistic nonuniform disk loading; below this point the inaccuracy increases, due to the rapid rolling up of the trailing-vortex system and the alteration of the wake vortex pattern behind the rotor; at locations well behind the rotor, the induced flow may be determined more accurately by assuming the rotor to be a uniformly loaded rectangular wing if the rotor lift coefficient is sufficiently high; and the Mangler and Squire induced-velocity calculations can be modified to account for the wake crossing the flow, according to the finite lift coefficient.

NORMAL COMPONENT OF INDUCED VELOCITY IN THE VICINITY OF A LIFTING ROTOR WITH A NONUNIFORM DISK LOADING. I - DEVELOPMENT OF INDUCED VELOCITY FIELDS BY SUPERPOSITION. H.H. Heyson. II - SYMMETRY RELATIONS AND THE RELATION BETWEEN RADIAL LOAD DISTRIBUTION AND THE RADIAL DOWNWASH DISTRIBUTION IN THE WAKE. S. Katzoff. US, NACA TN 3690, Apr., 1956. 45 pp. Results of calculations of the normal component for rotors having two different distributions - triangular and "typical" - in the longitudinal plane of symmetry and along the longitudinal and lateral axes, over a wide range of skew angles, presented in nondimensional chart form to illustrate the effect of nonuniform disk loading, and to be used as working charts for the determination of induced velocity at points in the field of practical rotors, indicate that the induced velocity at the center of any rotor which has zero load at its center (including all practical rotors) must be zero, and that rotor disk-load distribution has a large effect on the induced-velocity distribution and must be taken into account in estimating the effect of the rotor on most aircraft components. Results of the symmetry relation study in the plane of a uniformly loaded rotor, used to check the accuracy of calculated values and to provide directly the values of induced velocities along the lateral axis of the disk, indicate that: the sum of the induced velocities at points (x, y) and (-x, y) in the rotor disk is constant and equal to twice the induced velocity at the center; the induced velocity is constant all along the lateral diameter of the disk; and the sum of the induced velocities at points (x, y) and (-x, y) in the plane of, but outside, the rotor disk, determined from the two-dimensional flow about the ellipse that represents the wake cross section, equals the induced velocity at the corresponding point near the far wake. Results of the study of the radial distribution relationships of a nonuniformly loaded rotor indicate that, if the disk loading varies as the nth power of the radius, the induced velocity in the far wake varies similarly.

STRUCTURES

SOME FATIGUE CHARACTERISTICS OF A TWO SPAR LIGHT ALLOY STRUCTURE (METEOR 4 TAILPLANE). K.D. Raithby and Jenniffer Longson. Gt. Brit., RAE Rep. Struc. 195, Jan., 1956. 31 pp. Experimental investigation of the effects of mean and alternating load on the endurance, of low temperatures, of preloading, and of periodic overloading. Includes endurance curves for different mean loads, with results indicating that for a given alter-

nating load the endurance is roughly inversely proportional to mean load; that cut-outs lead to major skin failures which in turn increase spar boom stresses; that a single preload applied in the same sense as the mean load gives a marked increase in endurance under a fatigue loading of 25% $\pm$ 7.5% of the static failing load; and that an overload of 50% of the static failing load, applied periodically, increases the endurance approximately five times.

SOLUTION OF COMPLEX NONLINEAR PLASTIC STRUCTURES BY THE METHOD OF TEARING. Gabriel Kron. J. Aero. Sci., June, 1956, pp. 557-562. Development of a tensorial method to solve the stresses and deformations in complex statically indeterminate trusses stressed beyond the proportional limit. The method consists of tearing the plastic structure apart into smaller structures, or into its component bars, setting up nonlinear deformation-versus-stress equations of each small structure separately, and interconnecting the component nonlinear equations by tensorial methods.

BUCKLING OF AN INFINITE SIMPLY SUPPORTED STRIP UNDER COMBINED LONGITUDINAL COMPRESSION, TRANSVERSE COMPRESSION, BENDING, AND SHEAR. W.H. Wittrick. Australia, ARL Rep. SM.234, Sept., 1955. 41 pp. Solution of the problem using the Galerkin method to arrive at a comparatively simple approximate relationship between the four basic stress systems at buckling, with charts covering all possible combinations of the basic stress system.

ÜBER DIE VERWENDUNG VON BIPOLARKOORDINATEN ZUR LÖSUNG EINIGER PROBLEME DER PLATTENBIEGUNG. S. Woinowsky-Krieger. Ing.-Arch., No. 1, 1956, pp. 47-52. Analysis of the application of bipolar coordinates to the solution of such problems of the bending of plates as: a plate fixed between two circular profiles and subjected to uniform loading; a semi-circular plate under uniform loading; and a semi-circular plate under hydrostatic loading.

THERMAL SHOCK STRESSES IN A CYLINDER OF RECTANGULAR CROSS SECTION. P.W.H. Howe. Gt. Brit., NGTE Memo. M.263, Feb., 1956. 27 pp. Theoretical calculation, using relaxation methods, for one set of values of the length/width ratio of the rectangular cross section, heat transfer coefficient, and time after the quenching starts. Results indicate that the greatest surface tensile stress occurs at the corners, the next greatest at the mid-point of the short side, and the least at the midpoint of the long side.

INSTATIONÄRE WÄRMESPANNUNGEN IN HOHLZYLINDERN MIT KREISRINGQUERSCHNITT. R. Trostel. Ing.-Arch., No. 1, 1956, pp. 1-26. In German. Investigation of the state of stress caused by nonstationary, rotationally symmetrical temperature fields in hollow cylinders whose surfaces are subjected to local arbitrary thermal boundary effects. Results indicate that the extreme tangential and axial compressive stresses are stronger on the inner edge than the corresponding stresses on the outer edge and that in the case of a free cylinder the exteme tangential and axial compressive stresses are approximately equivalent to the tensile stresses.

VERTICAL TAKE-OFF AIRCRAFT

LIFT AND THRUST CREATING SYSTEMS - THEIR APPLICATION TO SHORT AND VERTICAL TAKE OFF AIRCRAFT. Karl Irbitis and F.C. Phillips. CAI Annual Gen. Meeting, Montreal, May 3, 4, 1956, Paper. 67 pp. Analysis of the principles of such lift- and thrust-producing systems as the wing, the ramjet, and the rocket. Includes a study of: the relationship between the wing and the ramjet; the possible motions of the wing; the whole family of wing-related systems from rotor to turbojet; high-lift modifications of the fixed wing, including flaps, slats, and boundary-layer control; and the application of the systems to the design of various vertical-take-off-and-landing (VTOL) and short-take-off-and-landing (STOL) aircraft. Results indicate that: the pressure jet helicopter is apt to be the most efficient type in terms of payload for VTOL short-range low-speed applications; the slipstream-deflection aircraft, basically an STOL type, approaches the pressure jet payload efficiency at short range, shows good efficiency over longer ranges, and cruises at speeds up to 500 m.p.h.; at speeds between Mach 0.7 to 2.0, where aerothermal effects become dominant, the VTOL coleopter type is capable of short range; and the VTOL flying disk shows longer range capability due to greater fuel stowage.

PRELIMINARY INVESTIGATION OF THE EFFECTIVENESS OF A SLIDING FLAP IN DEFLECTING A PROPELLER SLIPSTREAM DOWNWARD FOR VERTICAL TAKE-OFF. R.E. Kuhn and K.P. Spreemann. US, NACA TN 3693, May, 1956. 25 pp. Results of tests on a wing equipped with a sliding flap and a leading-edge slat conducted in a Langley Aero. Lab. static-thrust facility, which in comparison with a plain flap and a slotted flap previously tested makes possible a more forward location of the point at which flow turning begins. Results indicate that for a comparable downward deflection of the slipstream, the diving moments associated with the sliding-flap configuration are appreciably smaller than those of the slotted flap configuration. The addition of a leading-edge slat increases the turning angles achieved, particularly in the ground-effect region, and further reduce the diving moment.

WATER-BORNE AIRCRAFT

TOWING TANK TESTS TO DETERMINE THE WATER DRAG OF THE HULL OF A JET PROPELLED FLYING BOAT FIGHTER (SPEC. E.6/44) AND COMPARISON WITH FULL SCALE MEASUREMENTS. R.V. Gigg, A.C. Kurn, and J.K. Friswell. Gt. Brit., MAEE Rep. F/Res/263 (Revised). May, 1955. 41 pp. Measurements of the water drag, draft, wetted areas, and mean wetted lengths of the model hull for all anticipated take-off loads and attitudes over the take-off run. Application of a method of scaling up model drag to make allowances for the differences in skin friction, model, and full scale, with results compared to those of full scale tests.

WIND TUNNELS & RESEARCH FACILITIES

EXPERIMENTAL INVESTIGATION OF WATER FLOW THROUGH A MODEL OF ONE COOLING-WATER PASSAGE OF TUNNEL E-2 THROAT BLOCK. J.A. Durand. USAF AEDC TN-56-2, Apr., 1956. 26 pp. Results of tests for the determination of the volume flow of water as a function of inlet pressure, pressure drop through the passage, flow direction, and surface roughness of the passage. Includes a method for transforming the test data to the water-flow conditions through the Tunnel E-2 throat-block passages, and a calculation of the flow without separation from the walls of the model obtained by proper adjustment of valves in the inlet and outlet pipes.

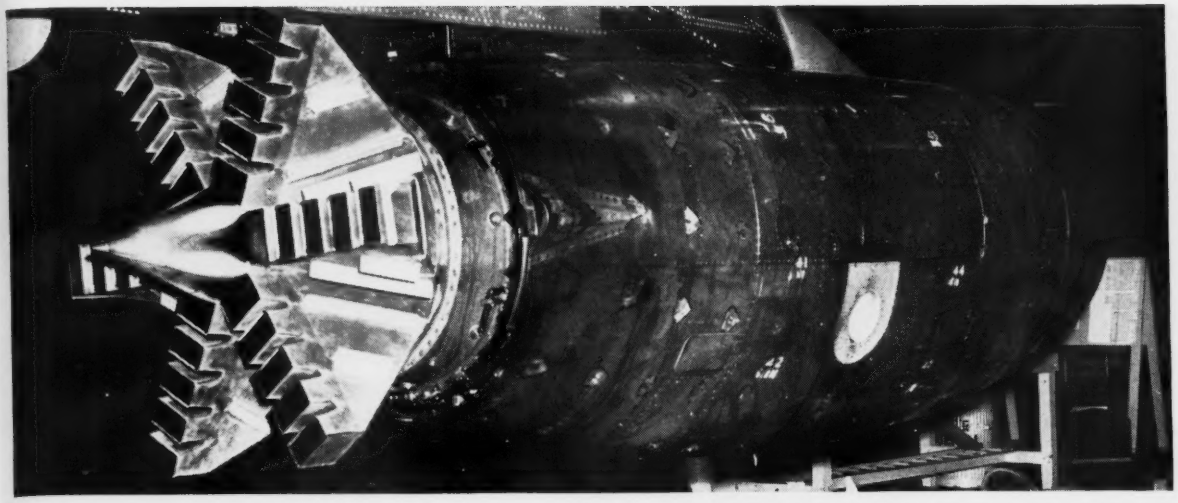
LINEARIZED THEORY OF WIND TUNNEL INTERFERENCE AT TRANSONIC SPEED. Toshimitsu Muraski. J. Japan Soc. Aero. Eng., Feb.-Mar., 1956, pp. 1-5. 17 refs. Theoretical study using the linearized theory extended to the three-dimensional lifting case at sonic and nearly sonic speeds and applicable to the nonlifting case in the field of Mach Number near one with boundaries at finite distances. For lifting and nonlifting bodies in the transonic range, the assumption of linearized relations for the boundary conditions at slotted or porous walls, indicates the superiority of the slotted wall over the porous.

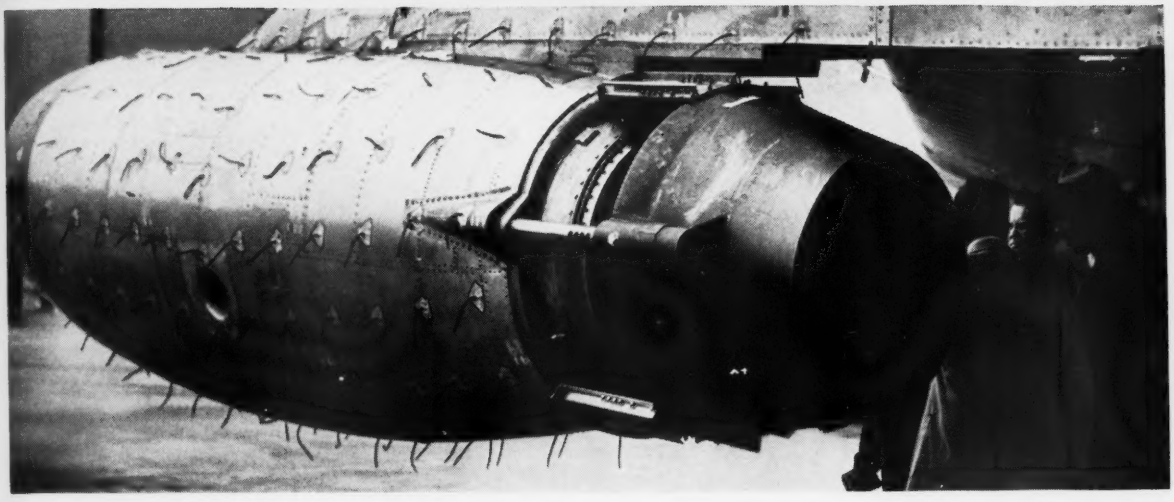
ON-LINE AUTOMATIC DATA REDUCTION TUNNEL E-1, GAS DYNAMICS FACILITY. C.L. Hall and R.E. Klautsch. USAF AEDC TN-56-4, Apr., 1956. 28 pp. Description of a system capable of measuring, scanning, computing, and presenting the results of a wind tunnel test in one continuous operation, with application of the operating modes of the system components to an actual test to obtain multiple temperature measurements, pressure measurements from traversing probe, and to take single pressure measurement on demand, and with a discussion of the versatility, reliability, and efficiency. Results indicate that: the servo-nulling instruments are in general free of operating faults when properly maintained; only two out of 25 binary converters have failed in use on-line during the first four months of operation; the system cabling is free of faults for an indefinite period when properly installed; the computing system requires stringent checking procedures; and a testing program using this system can be completed six to nine times faster than was previously possible.

INVESTIGATION OF A MULTIPLE-SOURCE SCHLIEREN SYSTEM FOR APPLICATION TO A PERFORATED WALL WIND TUNNEL. M. Pindzola and G.R. Mozer. USAF AEDC TR-56-1, Apr., 1956. 27 pp. Derivation of visibility equations indicating the influence of geometrical parameters on the background pattern, first for one, and then for two tunnel walls. Includes an analysis of the application of the system to observation of flow disturbances through transparent material of poor optical quality, and of an external source plate to increase system sensitivity. Results indicate that: the background pattern for a single wall of triangular hole pattern, when used as the source plate in a multiple-source schlieren system, is a function of the ratios of the hole spacing to hole diameter, of the lens-to-hole diameter, and of the distance between the source and object to the distance between the lens and object; a uniformly illuminated background pattern with no stacking of light rays can be attained at only a single plane between two walls of identical hole pattern and a fixed number of contributing holes; an acceptable pattern can be approached at other planes with a coplanar rotation of one wall with respect to the other, by application of a sufficient number of contributing rays per unit area; and the pattern obtained by relocation of the holes of the second wall in the two-wall case is a function of the ratio of the hole spacing to hole diameter of the source plate, the number of contributing rays per unit area, and the position of the object plane with respect to the walls.

ROLLING POWER MEASUREMENTS AND COMPARATIVE CALCULATIONS FOR A FLEXIBLE MODEL WING CONSTRUCTED FROM XYLONITE. N.C. Lambourne, A.S. Batson, and A. Chinneck. Appendix - APPLICATION OF LIFTING LINE THEORY. H.C. Garner. Gt. Brit., ARC R&M 2895, 1955. 35 pp. 12 refs. BIS, New York. $2.15. Theoretical and experimental investigation using the Collar-Broadbent method, based on strip theory, and the Garner method, based on lifting-line theory, including results of two early and more approximate methods. Results indicate that: Xynolite models give better representation than that offered by the types consisting of a wooden framework covered by silk; the stiffness of the replica model has to be truly representative of the full-scale structure; the skin thickness of the model should be within or above the minimum, which, for a normal size is probably in the region of 0.010 to 0.015 in., to achieve a reasonable aerodynamic surface; and Xynolite models are apt to be too stiff for the manifestation of aeroelastic effects in the tunnels commonly available, but this tendency disappears with the increase in the model size and the tunnel speed.

FABRICATION DE MAQUETTES A L'AIDE DES MATIÈRES PLASTIQUES. G. Dixmier. (France, ONERA NT 33, 1956.) 8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20-25, 1956. 61 pp. In French. Development of a method for the fabrication of dynamic models using reinforced plastics and taking into account similar properties of hydrodynamic models, to satisfy heavy test conditions, and to obtain dimensional stability, specified load resistance, degree of freedom, and surface finish. Study includes incorporation of metal frames in the construction; model types for stability and flutter tests, installation of flow visualization and pressure measuring apparatus, and control of balance gages; and light models to obtain dynamic similarity by the displacement of masses.





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Boeing aeronautical engineers play an important part in designing such advanced devices as the prototype sound suppressor (top) and thrust reverser (bottom), shown installed on the Boeing 707. On production 707 jet airliners, however, the two will be combined into a single unit capable of performing the duties of both the suppressor and reverser. Test results have been so satisfactory that Boeing has contracted to deliver 707s to airlines, beginning in late 1958, equipped with sound suppressor-thrust reversers.

Aeronautical engineers work closely with other engineers at Boeing in design and research for the 707, the KC-135 tanker-transport, the B-52 jet bomber, the BOMARC IM-99 weapons system, and aircraft of the future. Their work is challenging and creative, at the very frontiers of engineering knowledge in acoustics, structural design and flight testing, vibration, flutter, aerodynamics, and other specialties. Because of their record of solid achievement, Boeing "Aeros" stand professionally at the head of their field.

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Spring Tab Flutter. I—A Theoretical Investigation on Wing-Aileron-Tab Flutter. Appendix I—**Dimensions, Distortion Modes, and Elastic Stiffnesses of Aeroplane S.** Appendix II—**Inertial Coefficients.** Appendix III—**Air-Load Coefficients.** R. A. Frazer and W. P. Jones. **II—Experiments on Binary Aileron-Tab Flutter.** Appendix—**The Position of the Neutral Point for an Offset Balancing Arm.** C. Scruton, J. Williams, and C. J. W. Miles. *Gt. Brit., ARC R&M 2592*, 1955. 95 pp. BIS, New York. $5.75.

Stability Criteria for Linear Equations with Time-Varying Coefficients. Appendix—**Sonin's Theorem.** P. E. W. Grensted. *J. RAeS*, Mar., 1956, pp. 205–208. Definition of the conditions satisfied by the rates of change of the coefficients for the application of the Routh's criterion to the instantaneous values of the coefficients alone, with a derivation of a modified criterion based on the assumption that, to a first order, it depends only on the instantaneous values of the coefficients and their first derivatives, as applied to equations of any order, with results for equations of the second, third, and fourth order.

The Theoretical Determination of Normal Modes and Frequencies of Vibration. I. T. Minhinnick. *Gt. Brit., RAE Rep. Struc. 197*, Jan., 1956. 47 pp. 96 refs. Analysis of various methods evaluated in terms of accuracy and the amount of work entailed, with a numerical example to illustrate the comparison. Includes calculation of normal vibration modes of wings, fuselage, and tail units separately, based on the fundamental differential equation, the integral equation incorporating flexibility coefficients, and the Rayleigh or Lagrangian equation.

The Theory of Torsional Vibrations of a Four-Boom Thin-Walled Cylinder of Rectangular Cross-Section. Appendix I—**Effect of Boom Inertia in Axial Vibration.** Appendix II—**Increase in Stiffness Near the Root Due to Building-In.** E. H. Mansfield. *Gt. Brit., ARC R&M 2867*, 1955. 16 pp. BIS, New York. $1.25. Derivation of: a differential equation of motion based on the assumption that the ribs maintain the section shape without resisting any warping out of their plane, and that the walls of the cylinder are effective only in shear; and frequency equations for a length of cylinder, free at both ends and prevented from rotating at the mid-section. Includes a method of estimating the torsional frequencies of a cylinder with nonuniform characteristics.

The Unsteady Aerodynamic Forces on Deforming, Low Aspect Ratio Wings and Slender Wing-Body Combinations. Appendix I—**The Cropped Delta—Definitions and Geometrical Properties.** Appendix II—**Equivalent Constant Derivatives—Definitions.** Appendix III—**Results of a Calculation Using Uncoupled Modes.** Appendix IV—**"Rigid" Force Coefficients for a Slender Body of Revolution with Conical Nose.** Appendix V—**"Rigid" Force Coefficients for Triangular Wing on Cylindrical Body.** Appendix VI—**"Rigid" Force Coefficients for a Slender Wing-Body Combination.** R. D. Milne. *Coll. of Aeronautics, Cranfield, Rep. 94*, July, 1955. 45 pp. 21 refs.

Gust-Load and Airspeed Data from One Type of Two-Engine Airplane on Six Civil Airline Routes from 1947 to 1955. Appendix—**Details of Method of Evaluation and Analysis of Records.** Walter G. Walker. *U.S., NACA TN 3621*, Feb., 1956. 25 pp. 11 refs.

Preliminary Experiments on the Simulation of Gusts in a Wind Tunnel. A. M. Kuethe, J. D. Schetzer, L. C. Garby, and R. L. Roensch. *USAF TN 55-64*, Mar., 1955. 46 pp. 40 refs. Analytical evaluation of the relative merits of techniques for generating reproducible gusts in a wind tunnel applying the aerodynamic lift-lag theory.

Results of a Flight Investigation of Clear Air Turbulence at Low Altitude Using a Meteor Mk. 7 Aircraft. R. M. Allan. *Gt. Brit., RAE TN Aero. 2390*, Sept., 1955. 16 pp.

Theoretical Study of the Lateral Frequency Response to Gusts of a Fighter Airplane, Both with Controls Fixed and with Several Types of Autopilots. Appendix—**Calculation of Frequency Response of Airplane-Autopilot Combinations by Transfer-Function Method.** James J. Adams and Charles W. Mathews. *U.S., NACA TN 3603*, Mar., 1956. 46 pp.

Air Transportation

The Third Phase of Air Transport: Jet Transport. *Interavia*, Mar., 1956, pp. 163–188. Partial contents: Turbine Transport Experience, Miles Thomas. Will the Airlines Be Able to Operate Their Intercontinental Jet Transports? R. Dupre. The Coming Jet Transport Fleet. Some of the Problems in the Certification of Jet Transport Aeroplanes, H. C. Black.

Airplane Design

Assessing the Tu-104 (Twin Turbojet Soviet Transport). *Flight*, Apr. 6, 1956, p. 393.

Fail-Safe Airframe Design; The Lockheed Philosophy: "Fail-Safe" Preferred to "Safe-Life." *Flight*, Apr. 6, 1956, pp. 394–397. 11 refs.

French Imagination Scores in Caravelle Structure. Randolph Hawthorne. *Av. Age*, Mar., 1956, pp. 18–23, cutaway drawings. Design and structural characteristics.

The Problem of the Very Light-Weight, Highly-Efficient Aeroplane. B. S. Shenstone. *Can. Aero. J.*, Mar., 1956, pp. 83–90. 15 refs. Analytical evaluation of previous investigations covering aerodynamic effects such as drag, ground-effect, boundary layer control; structural refinements such as the Seehase wing; and propulsion units actuated by the pilot.

Airports

Traffic Control

Common System Development—1956. James L. Anast. (*IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 613.*) *Aero. Eng. Rev.*, May, 1956, pp. 98–101.

Summary of Joint FIL-TDEC Simulation Activities in Air Traffic Control. Appendix A—**Comparative Results and Discussion of Some Terminal Area Studies.** Appendix B—**Enroute Quantitative Measurement Program.** Samuel M. Berkowitz, Edward L. Fritz, Robert S. Grubmeyer, and Roger S. Miller. *Franklin Inst. Labs., TR F-2384*, Aug., 1955. 120 pp. 11 refs. Results of the investigation program for the evaluation of operational concepts of preliminary and finalized designs of equipment and techniques, and for the development of new and improved means of simulation.

Aviation Medicine

Human Engineering

Air Crew Fatigue and Flight Time Limitation. J. A. Newton. *J. RAeS*, Mar., 1956, pp. 186–190. Study of aeroneurosis phenomena including such factors as: the mental and physical health of the pilot, anticipatory tension, ground rest and mess conditions, schedule delays, length of flight, and rest facilities and difficulties in actual operation of the aircraft.

Acceleration Force and the Space Pilot. J. J. Raffone. *J. Astronautics*, Fall, 1955, pp. 100–104. Results of tests on a human centrifuge on the effects of acceleration force measured in positive and negative *G* units, with an evaluation of the relative merits of the supine position during acceleration periods.

Accuracy of Positioning Responses as a Function of Spring Loading in a Control. Harry P. Bahrick, William F. Bennett, and Paul M. Fitts. (*J. Exper. Psych.*, June, 1955, pp. 437–444.) *USAF PTRC TN-55-31*, Oct., 1955. 8 pp.

Complex Tasks for Use in Human Problem-Solving Research. Wilbert S. Ray. (*Psych. Bul.*, Mar., 1955, pp. 134–149). *USAF PTRC TN-55-43*, Nov., 1955. 16 pp. 39 refs.

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The Frequency Response of Skilled Subjects in a Pursuit Tracking Task. Merrill Noble, Paul M. Fitts, and Claude E. Warren. (*J. Exper. Psych.*, Apr., 1955, pp. 249–256.) *USAF PTRC TN-55-42*, Nov., 1955. 8 pp. 14 refs.

Perception of Place in a Circular Field. Fred Attneave. (*Am. J. Psych.*, Mar., 1955, pp. 69–82.) *USAF PTRC TN-55-44*, Nov., 1955. 14 pp.

Computers

Computing Mechanisms. I. *Prod. Eng.*, Mar., 1956, pp. 200, 201. Basic design and principles; applications.

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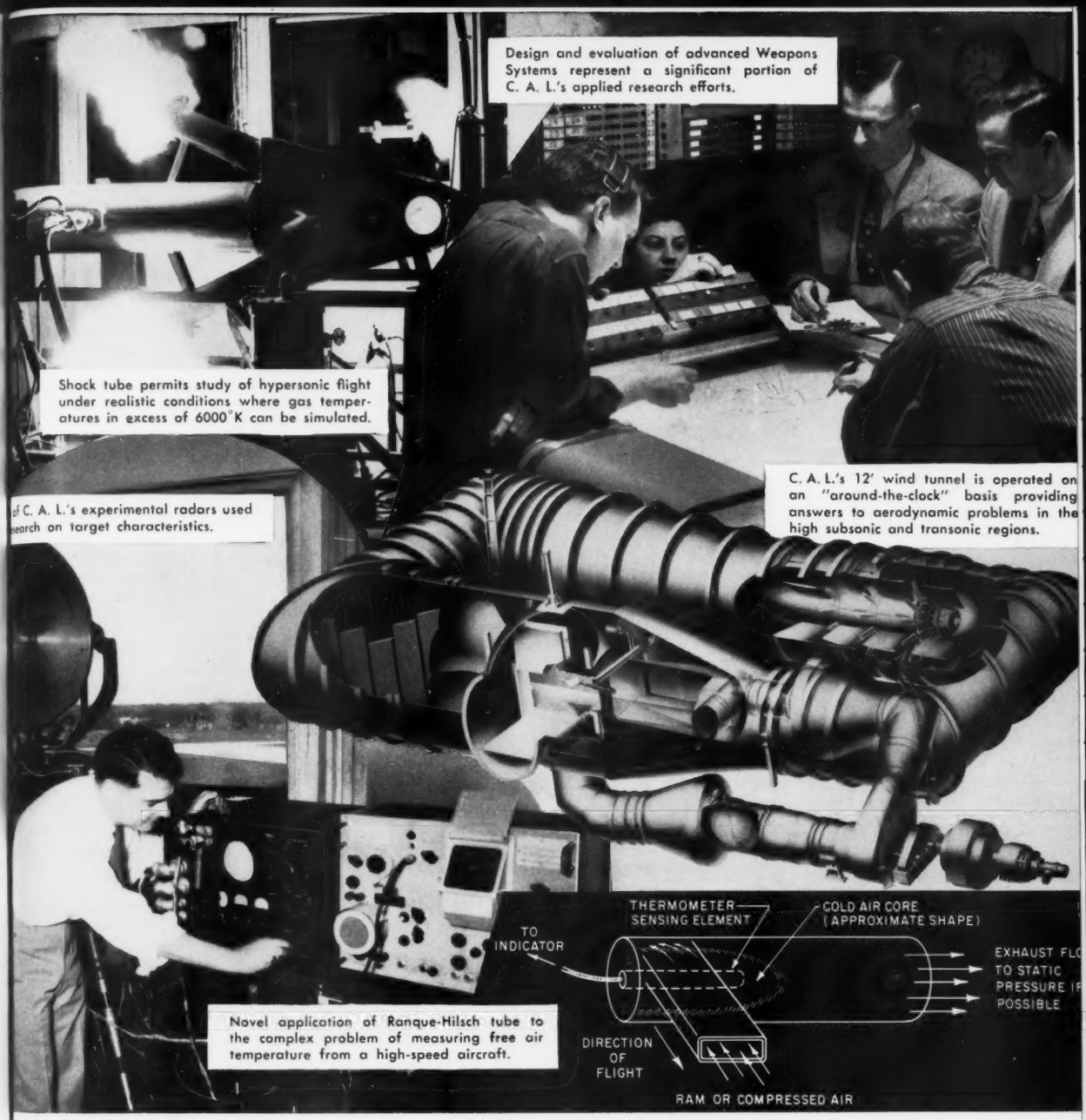
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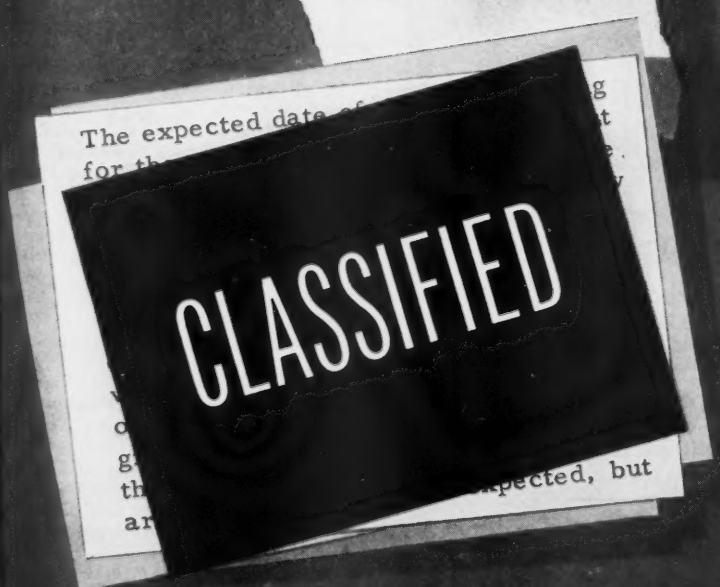

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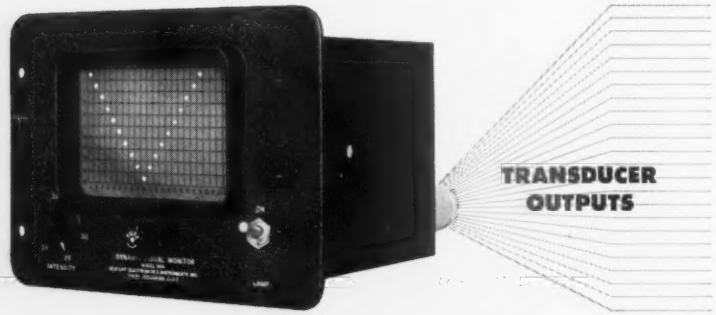

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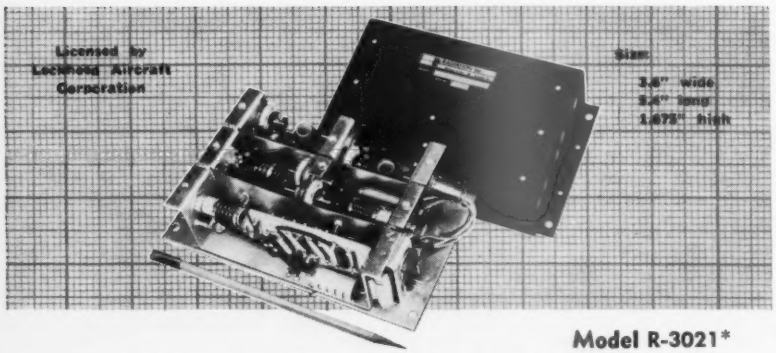

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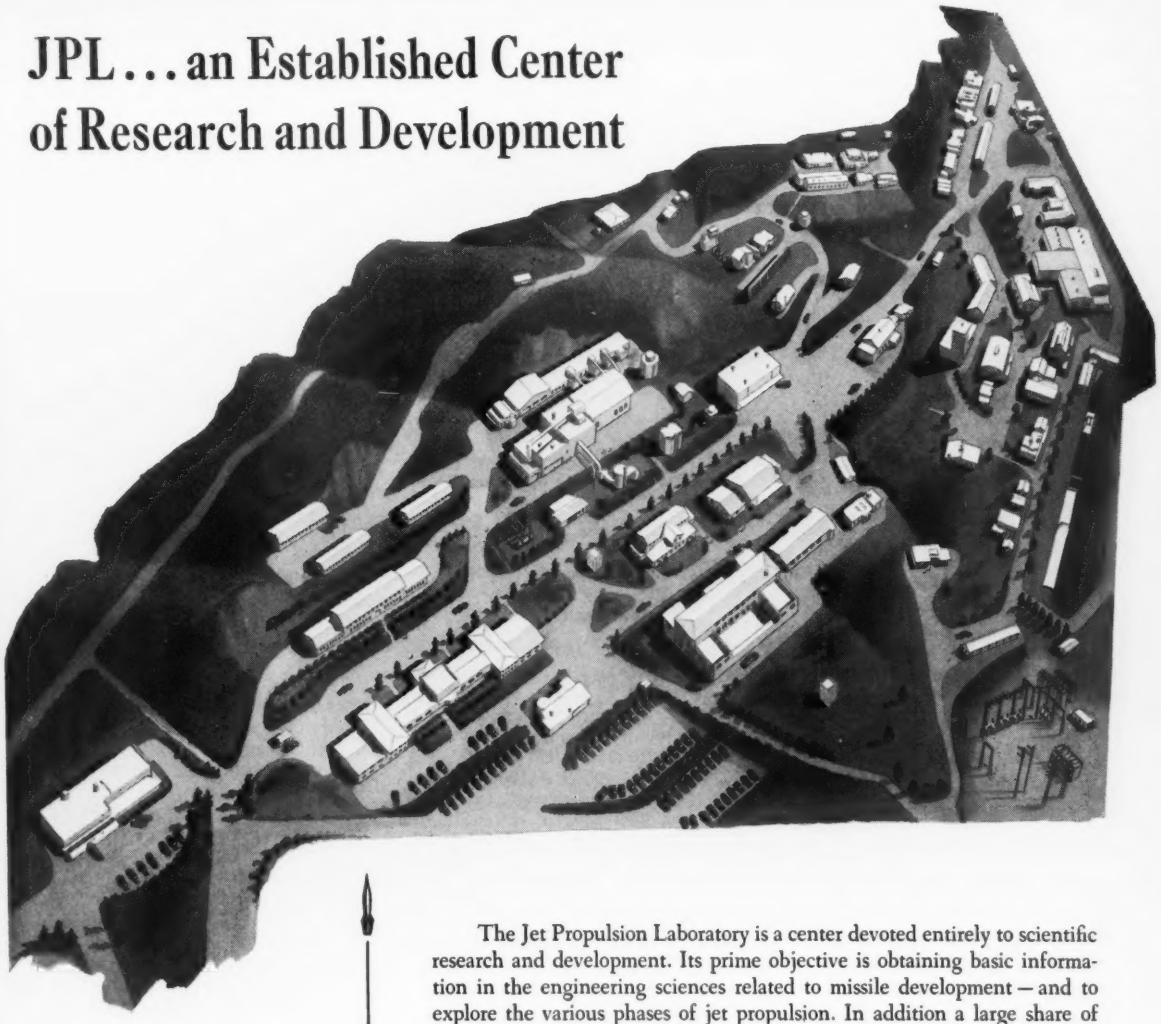

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Materials

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Missiles

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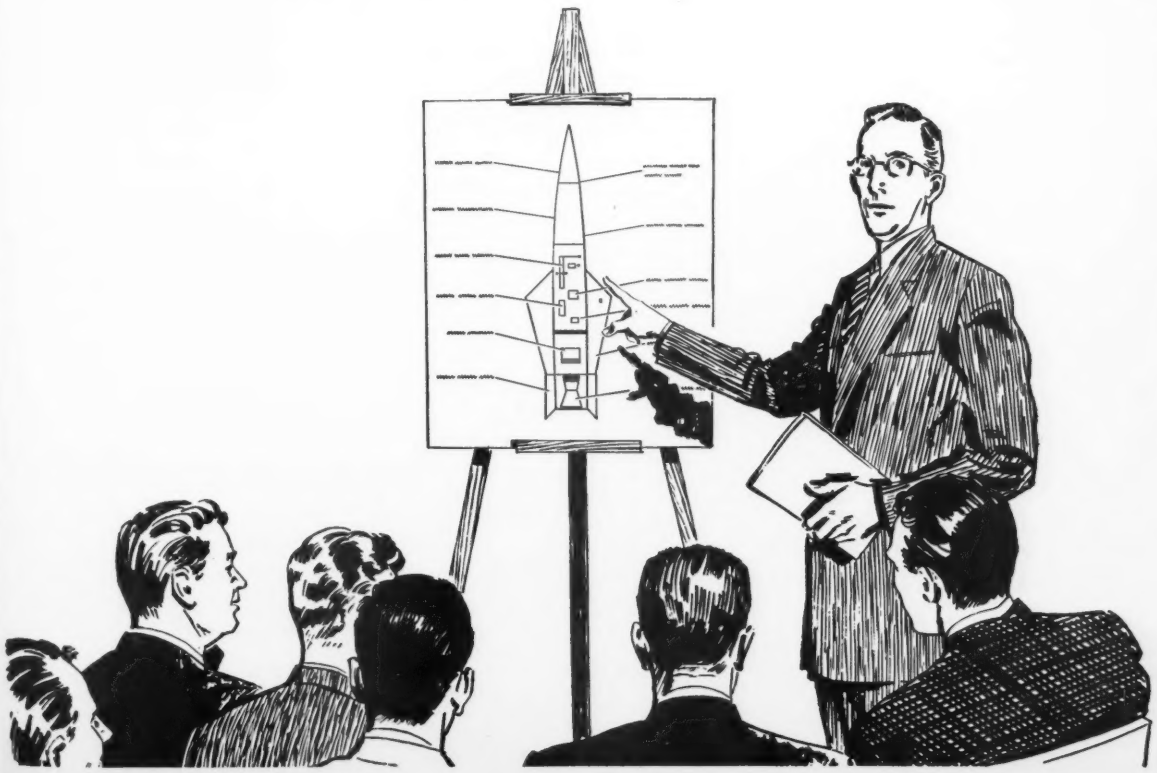

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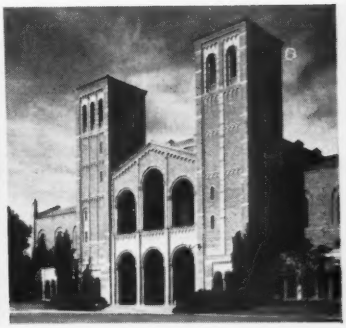

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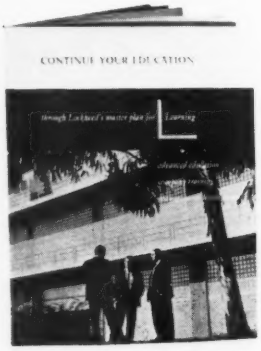

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L'Inviluppo delle Condizioni di Volo per Gli Aerogiri (Flight Envelope for Rotorcraft). Renato Vannutelli. *L'Aerotecnica* (Rome), Oct., 1955, pp. 230–234. In Italian. Analysis of the relative merits; application to convertiplanes and rotorcraft of particular design, with criteria for plotting stall- and gust-curves in terms of airworthiness requirements.

On the Use of a Tensor Transformation to Describe the Rotation of a Rigid Body; with Applications to a Wing of Variable Sweep and a Retractable Undercarriage. E. H. Bateman. *Gt. Brit., RAE Rep. Struc. 190*, Oct., 1955. 20 pp. Derivation of a general solution based on a tensor transformation to determine the position of a rigid body after rotation of a known axis.

Some Aspects of Night and Instrument Flying on Single Rotor Helicopters. D. A. Wilkinson. *Gt. Brit., AAEE Rep. Res/291*, Jan. 27, 1956. 29 pp. Results of investigations including ground lighting equipment and patterns, approach path angles, entry into restricted sites, use of parachute flares during emergency landing, and cockpit lighting. Includes an evaluation of the Thorne lighting installation on Sycamore Mk. 3 pilot panel and an experimental analysis of the effects of failure of single or grouped instruments.

Effect of Spanwise and Chordwise Mass Distribution on Rotor Blade Cyclic Stresses. Harold Hirsch, Robert E. Hutton, and Abner Rasumoff. *IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 637*. 14 pp. Members, $0.50; nonmembers, $0.85. Results of theoretical and experimental investigations covering model and XH-17 helicopter flight tests indicate a twisting of the blade due to the coupling of chordwise mass distribution with blade bending motion producing a cyclic airload and affecting the dynamic bending response of the blade and the influence of the spanwise mass distribution affecting primarily the blade beamwise natural frequency on the control of blade resonance effects.

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Investigation of High Length/Beam Ratio Seaplane Hulls with High Beam Loadings; Hydrodynamic Stability. XIV—The Effect of a Tailored Afterbody on Stability and Spray Characteristics with Test Data on Model J. D. M. Ridland. *Gt. Brit., MAEE Rep. F/Res./249,* Oct., 1955. 40 pp. 16 refs.

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Wind Tunnel Tests on Seaplane Hulls in the R.A.E. 5ft. Diameter Open Jet Tunnel and the N.P.L. Compressed Air Tunnel. A. G. Smith. *Gt. Brit., MAEE Rep. F/Res/266,* Jan., 1955. 77 pp. Summary of the data of tests over a range of 2 to 60 × 10^6 Reynolds Numbers to determine the origin and order of the component drags of a hull and the difference from that of an equivalent body of revolution, to evaluate the scale effects and the possible effect of controlling the boundary layer transition, and the "Princess" flying boat step fairing design.

The Theoretical Dynamic Longitudinal Stability of a Constant-Lift Hydrofoil System. Frederick H. Imlay. *U.S., Navy Dept., David W. Taylor Model Basin, Rep. 925,* Dec., 1954. 9 pp. Analytical results of an idealized system of hydrofoils not piercing the surface.

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Evaluation and Calibration of Wire-Strain-Gage Wind-Tunnel Balances Under Load. Raymond M. Hansen. *8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20–25, 1956.* 20 pp.

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Problems Involved in Precision Measurements with Resistance Strain Gages. Keith H. McFarland and John Dimeff. *8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20–25, 1956, Paper.* 20 pp. 13 refs. Study of the mechanical, electrical, and environmental effects on strain gage accuracy, taking into account such factors as: electrical resistance heating, environmental temperature changes, thermoelectric effects, leakage due to grounding, hysteresis, and bonding effects.

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An Investigation of the Lift, Drag, and Pitching Moment Characteristics of AGARD Calibration Models A and B. C. J. Schueler and W. T. Strike. *USAF AEDC TN-55-34,* Feb., 1956. 49 pp. 17 refs. Tests in E-1 Gas Dynamics Tunnel (AEDC) covering the 2.0–4.0 Mach Number and 1.5 × 10^6–27 × 10^6 Reynolds Number range for model A, and Mach 1.7–4.0 and Reynolds Number 3 × 10^6–22 × 10^6 for model B.

Model Selection and Design Practices Applicable to the Development of Specific Aircraft. Donald D. Beals. *8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20–25, 1956, Paper.* 29 pp. 14 refs. Discussion of the pertinent background information relative to a specific model development program, the major aerodynamic and mechanical requirements of model design, and the array of models required for a typical development program in the U.S., in terms of the aerodynamic problems of the air-frame, including the influence of inlets.

AGARD Correlation of Spin Tests; A Particular Study on FIAT G.82 Test Data. G. Gerza and G. Ciampolini. *8th NATO AGARD Wind-Tunnel and Model-Testing Panel Meeting, Rome, Feb. 20–25, 1956, Paper.* 34 pp. Investigation of the spin characteristics of an aircraft with full and empty tip-tanks combined with medium aileron deflections comparing the results of full-scale flight and tunnel tests.

IAS Twenty-Fifth Annual Meeting

Hotel Sheraton-Astor, New York City, January 28—31, 1957

The Meetings Committee plans to schedule sessions on Aerodynamics, Aeroelasticity, Design, Electronics, Flight Propulsion, Instruments, Rotating Wing Aircraft, Safety in Flight, Structures, Air Transportation, etc.

Members or organizations wishing to have papers considered for presentation at this meeting should submit outlines or short abstracts to the Meetings Committee, 2 East 64th St., New York 21, N.Y., no later than August 15, 1956.

Aeronautical Reviews — BOOKS

ACOUSTICS, SOUND, & NOISE

Handbook of Acoustic Noise Control. Vol. 1, Physical Acoustics. Edited by R. H. Bolt, S. J. Lakasik, A. W. Nolle, A. D. Frost (Bolt, Beranek, and Newman, Inc.). **Vol. 2, Noise and Man.** Walter A. Rosenblith, Kenneth N. Stevens, and the Staff of Bolt, Beranek, and Newman, Inc. (U.S. Air Force, Wright Air Development Center, WADC Technical Report No. 52-204; Vol. 1, December, 1952; Vol. 2, June 1953.) Washington, Office of Technical Services, Department of Commerce, 1955. Vol. 1, 397 pp., illus., diagrs., tables; PB-111200, $4.00. Vol. 2, 262 pp., illus., diagrs.; PB-111274, $3.00.

The handbook is intended to provide an overall view of the noise control problem. Taken into consideration are not only those problems of a purely physical or biological nature but also the varied factors of economics, operations, and planning. Acoustic noise can produce pain and damage to personnel, it can interfere with speech communication, and it can cause annoyance and general degradation of environment for work and relaxation. These matters are the subject of Volume 2, in which the several subjective responses are analyzed and correlated with properties of the physical stimuli. Volume 1 is concerned with the stimuli themselves, their generation, and their control.

Contents: Volume 1, *Physical Acoustics:* (1) General Aspects of Noise Control. (2) Terminology and Measurements. (3) The Specification of a Noise Source. (4) Aircraft Propellers and Reciprocating Engines. (5) Aircraft Jet and Rocket Engines. (6) Fluid Flow Devices. (7) Industrial Machine Noise. (8) Physical Characteristics of Miscellaneous Environmental Noise. (9) General Planning. (10) Noise Control Requirements. (11) Control of Structure-borne Noise. (12) Control of Airborne Noise. (13) Rooms and Special Enclosures. (14) Evaluation of Sound-Control Installations.

Contents: Volume 2, *Noise and Man:* (15) Bio-Acoustics: Terminology and Literature. (16) Basic Bio- and Psycho-Acoustic Data. (17) Effects of Noise on Human Behavior. (18) Human Response Criteria for Noise Control.

Handbook of Acoustic Noise Control: Vol. 1, Physical Acoustics, Supplement. Edited by Stephen J. Lukasik and A. Wilson Nobel (Bolt, Beranek, and Newman, Inc.). (U.S. Air Force, Wright Air Development Center, WADC Technical Report No. 52-204, April, 1955.) Washington, Office of Technical Services, Department of Commerce, 1955. 308 pp., diagrs. PB-111-200S, $6.00.

The present supplement contains only revisions to Volume 1, which was compiled in December, 1952. The changes are of two basic types: new sections on subjects not covered in Volume 1 and new sections reflecting changes in theory or practice. The revised chapters and chapter sections are as follows: (4.1) Propeller Noise. (4.2) Noise from Aircraft Reciprocating Engines. (4.3) Total External Noise from Aircraft with Reciprocating Engines. (6.3a) Noise Generating Mechanisms in Axial Flow Compressors. (6.5) Ventilating Fans and Ventilating Systems. (11.2) Insulation of Airborne Sound by Rigid Partitions. (11.3) Insulation of Impact Sound. (11.5) Transmission of Sound Through Cylindrical Shells. (12.1) Specification of Sound Absorptive Properties. (12.2) Lined Ducts. (12.6a) The Resonator as a Free-Field Sound Absorber. (12.9) Acoustical Shielding by Structures.

AERODYNAMICS

Theoretical Hydrodynamics. 3rd Ed. L. M. Milne-Thomson. New York, The Macmillan Co., 1955. 632 pp., illus., diagrs. $9.80.

The author is Professor of Mathematics, Royal Naval College. His book is based upon lectures on hydrodynamics given at Greenwich to junior members of the Royal Corps of Naval Constructors. A second edition published by Macmillan appeared in 1950. Apart from rearrangements and new methods of presentation, the present edition differs from the second by three additions: C. G. Darwin's interpretation of virtual mass, M. Shiffman's method of reflection across free streamlines, and F. John's treatment of potential flow with a free surface.

AERONAUTICS, GENERAL

Proceedings of the Conference on High-Speed Aeronautics. Sponsored by the Polytechnic Institute of Brooklyn. Edited by Antonio Ferri, N. J. Hoff, and Paul A. Libby. Brooklyn, N.Y., Polytechnic Institute of Brooklyn, 1955. 392 pp., illus., diagrs. $5.25.

Contents: An Account of the Conference, N. J. Hoff. Solved and Unsolved Problems of High-Speed Aerodynamics, Theodore von Kármán. Transition from Laminar to Turbulent Flow at Subsonic and Supersonic Speeds, Hugh L. Dryden. Considerations on the Shock-Boundary Layer Interaction, Luigi Crocco. The Flow Around Bodies of Revolution at Mach Number 1, K. Oswatitsch and F. Keune. The Relation Between Minimizing Drag and Noise at Supersonic Speeds, Adolf Busemann. Possibilities of Efficient High-Speed Transport Airplanes, Robert T. Jones. An Experimental Contribution to the Study of the Lifting Airfoil at Transonic Speeds, Roger R. Michel and Maurice J. J. Sirieix. Some Problems of Cascade Flow, H. Schlichting. Balance Method in Thermal Stress Analysis, Luigi Broglio. High Temperature Structural Research at the National Advisory Committee for Aeronautics, John Duberg. The Influence of Kinetic Heating on the Design and Testing of Aircraft Structures, W. H. Horton. Stress Distribution in the Presence of Steady Creep, N. J. Hoff. Test Facilities for Ultra-High Speed Aerodynamics, Ronald Smelt. A Survey of Physical Phenomena Occurring in Flight at Extreme Speeds, Arthur Kantrowitz. Recent Theoretical Work in Supersonic Aerodynamics at the Polytechnic Institute of Brooklyn, Antonio Ferri. Facilities for Experimental High Speed Aerodynamic Research at the Polytechnic Institute of Brooklyn, Paul A. Libby and Martin H. Bloom.

Proceedings of the Fifth AGARD General Assembly, Canada, June 10–17, 1955. (NATO, Advisory Group for Aeronautical Research and Development, AG 20/P10.) Ottawa, Printed by Edmond Cloutier, Queen's Printer and Controller of Stationery, 1956. 157 pp., illus., diagrs. United States Distribution by NACA, Washington, D.C.

This volume contains the addresses, general lectures, and summaries of panel meetings presented to the Assembly. Included is a bibliography of the 47 papers presented at the different panel meetings; the papers themselves are not a part of this volume. The technical papers given at the General Assembly are: History of Aeronautical Research and Development in Canada, J. H. Parkin. RCAF Development of Automatic Navigation System, J. G. Wright. Advancing Temperature Frontiers: Round Table Discussion. Aerodynamic Heating Versus Speed: Thermodynamic Aspect of the Struggle, Maurice Roy. The Structural Effects of Kinetic Heating in Supersonic Flight, P. B. Walker. Man's Response to Temperature Extremes, A. P. Gagge. Where Are the Limits of Combustion Intensity, J. J. Broeze. Aeroelastic Effects of Aerodynamic Heating, H. L. Dryden and J. E. Duberg. Increasing the NATO Research and Development Potential: Round Table Discussion.

AVIATION MEDICINE

Medical Support of the Army Air Forces in World War II. Mae Mills Link and Hubert A. Coleman. (Department of the Air Force, Office of the Surgeon General.) Washington, D.C., U.S. Government Printing Office, 1955. 1,027 pp., illus., diagrs., tables. $7.00.

The authors present a unified narrative of the total performance of the AAF medical service in support of the Air Forces combat mission. It has taken 10 years to compile, write, edit, and print this volume. Though the authors assume final responsibility for historical and technical accuracy in the presentation and interpretation of the material, there are individual contributions by the Army Air Forces Training Command under the direction of Col. Neeley Mashburn (MC); the School of Aviation Medicine; the Staff of the Aero Medical Laboratory; the School of Air Evacuation; the Air Transport Command; John S. G. Carson, Ph.D.; Col. William Cook (MC); Wiley Hodges, Ph.D.; Lt. Col. Charles G. Mixter, Jr. (MC); and Bruce Berman, M.A. Fundamentally a reference work, material is based almost exclusively upon unpublished documents in custody of the U.S. Air Force. The volume portrays in detail the problems faced by AAF and the measures taken to solve them. In the hope that this history will provide a basic guide for younger officers who may again be

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faced with similar problems, the processes by which certain policy decisions were reached are described in detail. The scope of the material should also prove of value to the military and civilian planner who is concerned with the problem of manpower and to the doctor who wishes an insight into the role of the medical profession in a national emergency. Because of the interest in the human element, it is possible to recommend the volume for general reading.

Each chapter is thoroughly documented and concludes with footnote references. There are 97 tables, and 19 charts are used to point up such information as Radius of Aircraft Turn Required to Blackout Average Pilot at Various True Speeds, and Human Factors in Aircraft Design. Overall the volume is highlighted by 52 photographic illustrations that show personnel, materials, equipment, theaters of operation, and operational procedures.

Contents: (1) Origins of an Air Force Medical Service. (2) The War Mission. (3) School of Aviation Medicine and Related Programs. (4) Research and Development. (5) Air Evacuation Mission. (6) Medical Support of Air Combat in North Africa and the Mediterranean. (7) Medical Support of Air Combat in Europe. (8) Special Problems in Aviation Medicine in Europe. (9) Medical Support of Air Combat in the Pacific. (10) Medical Support of Air Combat in China-Burma-India. (11) Medical Support of the Very Long Range (VH) Bomber Program.

DIRECTORIES

Who's Who in Electronics, 1956. Cleveland, H. Marlet, 1956. 426 pp., illus., diagrs.

This directory is a primary supply-source guide to electronic parts and equipment. It consists of 3 basic divisions: a Manufacturers Index, a Representatives Roster, and a Distributor Roster. The Manufacturers Index contains an alphabetical list of manufacturers, an alphabetical list of trade names, and a Products Section with over 250 product classifications and 2,000 manufacturers. The Representatives Roster lists manufacturers' representatives both alphabetically and geographically by state and city. The Distributor Roster is arranged geographically and lists distributors of electronic parts and equipment.

DRAFTING

Aeronautical Drafting Manual. 6th Rev. Ed. New York, Society of Automotive Engineers, Inc., 1956. 210 pp., diagrs. Loose-Leaf. $4.50.

The original manual issued in 1941 dealt only with aircraft engine drafting practices. The present edition has been expanded to include practices that apply to the aircraft propeller accessory industries, as well as to air-line operators. The loose-leaf form of the book permits material to be kept up-to-date; additions and revisions are issued as necessary.

ELECTRONICS

Electronics in Management. Edited by Lowell H. Hattery and George P. Bush. Washington, D.C., The University Press of Washington, 1956. 207 pp. $6.00.

This volume summarizes advanced thinking on the implications to management arising from the development and installation of automatic systems, especially data-processing systems. The material is adapted from the proceedings of the First Institute on Electronics in Management presented at The American University in November, 1955. To provide a setting for the contributors who explore the problem areas of planning, procedures, organization, personnel, fiscal, and executive, the editors review the outlook for the impact of electronic data-processing equipment on the new dimensions of management. The complex field of hardware is discussed, but no attempt is made to present either the engineering or electronic computing machinery or the detailed technical characteristics of currently available equipment. The primary emphasis remains on the contribution of electronic computing systems to man-

agement and management's challenge to integrate these systems into its operations.

Contents: (1) Management Impact of Electronic Systems, Lowell H. Hattery. (2) Development of Automatic Computers, Franz L. Alt. (3) European Experience with Electronic Computers, S. N. Alexander. (4) Tailored Electronic Equipment, F. D. Rigby. (5) Evaluation and Selecting Equipment, William Howard Gammon. (6) Potentialities and Problems of Electronic Data Processing in the Census Bureau, Morris H. Hansen and James L. McPherson. (7) Logistics Application in the Air Force, Saul Hoch. (8) Logistics Application in the Aviation Supply Office, F. L. Hetter, V. A. Blandin, and W. V. Crowley. (9) Treasury Department Check Reconciliation Project, George F. Stickney. (10) Cost Considerations, George P. Bush. (11) Procedural Changes for Electronic Systems, James T. Scott. (12) Personnel and Training Needs, Robert D. Acker. (13) Preparing Employees for the Changeover, Robert B. Curry. (14) Management Experience in the Census Bureau, Donald H. Heiser. (15) Organizational Effects, Walter F. Frese. (16) Executive Problems and Opportunities, Leo C. Simmons. (17) Management Forecast, G. T. Hunter.

Electronics. A. W. Keen. New York, Philosophical Library, 1956. 255 pp., illus., diagrs. $7.50.

A book for the nontechnical reader and student which serves as an introduction to electronic devices and their applications. The treatment is entirely descriptive. The author has been, since 1952, a lecturer on electronics and telecommunications at Coventry Technical College.

LAWS & REGULATIONS

Legal Problems in Engineering. Melvin Nord, New York, John Wiley & Sons, Inc., 1956. 391 pp. $7.50.

A book designed for reference use by engineers and prepared for especial use as a college textbook. The scope of the work brings in almost every legal subject that has any bearing on engineering. Excluded are detailed documentary examples, such as specifications and economic topics, except where they affect the law or its engineering aspects. The book uses its cases to illustrate the discussion and to point up the legal problems which may be encountered in given circumstances. Cases are presented in a condensed form, and involved legal phraseology has been held to a minimum. "Problems" are given at the end of each chapter; the "answers" are left to the resources of the student. At present, the author is a consultant in law and engineering and, since 1950, has lectured on law and engineering at Wayne University.

Civil Air Regulation and Reference Guide for A & E Mechanics. 13th Ed. Associated Aeronautical Staff of Aero Publishers. Los Angeles, Aero Publishers, Inc., 1956. 120 pp., diagrs. $2.00.

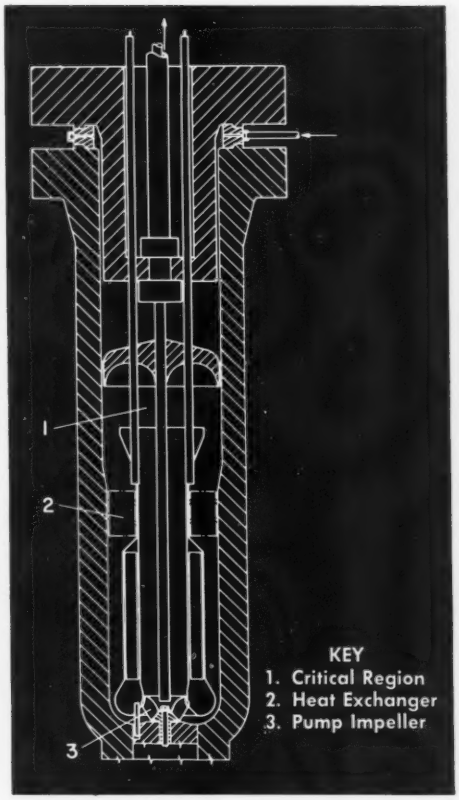
The volume contains all of the Civil Air Regulations that are required and recommended by the CAA for A & E Mechanics. It also furnishes a reference guide of questions and answers on CAR's that are similar to those asked by the CAA for the Certificates and copies of the inspection forms.

MATERIALS

High-Temperature Technology. I. E. Campbell, Editor-in-Chief. Sponsored by The Electrochemical Society, Inc., New York, John Wiley & Sons, Inc., 1956. 526 pp., illus., diagrs., tables. $15.

This monograph describes both the recent developments in the field and the importance of established techniques and materials to modern high-temperature technology. The thirty-five contributors are metals engineers, metallurgists, ceramists, and chemists who present the highlights of their research in the field. The book is divided into four sections: an Introductory Section tracing the development of modern refractories and modern high-temperature techniques;

1 of 5



This simplified drawing of an experimental homogeneous type power reactor, now in the final assembly stage, shows one of five nuclear reactor projects currently under way at Los Alamos, where the world's first homogeneous reactor was designed and built and is still in operation.

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a Materials Section; a Methods Section; and a Measurements Section. The Materials Section discusses such refractory materials as oxides, carbon, graphite, and carbides. A review is also given of the newer refractory materials such as the silicides, nitrides, sulfides, and the cermets. Discussions of the fluorides, oxyfluorides, oxysulfides, and phosphides have not been included. The Methods Section presents a detailed discussion of sintering and various types of furnaces for securing very high temperatures. The final section is devoted to a critical discussion of temperature and equipment for its measurement. Included are selective discussions of various specialized mechanical and physical property tests and specially devised high-temperature optical and X-ray techniques. Author and subject indexes together with a bibliography accompanying each article help to make this an effective reference volume.

1955 Book of ASTM Standards, Including Tentatives. Philadelphia, American Society for Testing Materials, 1955-56. 7 vols., illus., diagrs., tables. $84 the set.

Part 1, Ferrous Metals, 1,802 pp. Part 2, Non-Ferrous Metals, 1,482 pp. Part 3, Cement, Concrete, Ceramics, Thermal Insulation, Road Materials, Waterproofing, Soils, 2,020 pp. Part 4, Paint, Naval Stores, Cellulose, Wax Polishes, Wood, Acoustical Materials, Sandwich and Building Constructions, Fire Tests, 1,386 pp. Part 5, Fuels, Petroleum, Aromatic Hydrocarbons, Engine Antifreezes, 1,460 pp. Part 6, Plastics, Electrical Insulation, Rubber, Electronics Materials, 1,738 pp. Part 7, Textiles, Soap, Water, Paper, Adhesives, Shipping Containers, Atmospheric Analysis, 1,658 pp.

The Book of ASTM Standards is a triennial publication with Supplements issued in the intervening years. "Standards" comprise those specifications and methods of test that have been formally adopted by the Society, requiring a letter ballot approval. "Tentatives" have been approved by the sponsoring committee as representing the latest thoughts and practices and have been accepted by the Society in accordance with established procedures for use pending adoption as standard. The 1955 edition comprises over 11,000 pages and includes more than 2,100 specifications tests and definitions for materials. Each volume of the set is complete with detailed subject index and two tables of contents and is arranged to provide as usable a book as possible for technologists and others in industry and government who must purchase materials or evaluate their quality through standard tests. A supplementary volume providing a combined index to the standards and incorporating the latest references to the standards and their supplements will be issued and revised annually.

Symposium on Effect of Temperature on the Brittle Behavior of Metals; with Particular Reference to Low Temperatures. Atlantic City, June 28-30, 1953. (Special Technical Publication No. 158.) Philadelphia, American Society for Testing Materials, 1954. 474 pp., illus., diagrs., figs. (Corrected price) $7.50.

MATHEMATICS

Tables of the Function arc sin *z*. By the Staff of the Computation Laboratory. (Harvard University, Computation Laboratory, Annals, Vol. 40.) Cambridge, Mass., Harvard University Press, 1956. 586 pp. $12.50.

The tabulation of the inverse circular sine for complex argument was undertaken at the request of the Aeronautical Research Laboratory of the USAF. After a preliminary analysis by J. Orten Gadd, the problem was assigned to Jagna Zahl who completed the organization of the problem, programmed it for the Mark IV Calculator, and supervised its operation on the machine. Unlike all other known tables of arc sin *z*, both the argument and the function are given in cartesian form, and six decimal places are provided. Pseudo differences (or alternative methods) are given in order to provide interpolation to within an error of 2×10^6 by second-order interpolation. Besides the tables, the volume contains an introduction which describes the properties of the function, the composition of the tables, and methods for interpolation in the light of the accuracy required.

MECHANICS

Surveys in Mechanics; A Collection of Surveys of the Present Position of Research in Some Branches of Mechanics, Written in Commemoration of the 70th Birthday of Geoffrey Ingram Taylor. Edited by G. K. Batchelor and R. M. Davies. Cambridge, England, and New York, Cambridge University Press, 1956. 475 pp., illus., diagrs., tables. $9.50.

Contents: G. I. Taylor: A Biographical Note, R. V. Southwell, Cambridge. The Mechanics of Quasi-Static Plastic Deformation in Metals, R. Hill, Department of Mathematics, University of Nottingham. Dislocations in Crystalline Solids, N. F. Mott, Cavendish Laboratory, University of Cambridge. Stress Waves in Solids, R. M. Davies, Department of Physics, University College, Aberystwyth. Rotating Fluids, H. B. Squire, Department of Aeronautics, Imperial College of Science and Technology, London. The Mechanics of Drops and Bubbles, W. R. Lane and H. L. Green, Chemical Defence Experimental Establishment, Porton, Wiltshire. Wave Generation by Wind, F. Ursell, King's College, Cambridge. Viscosity Effects in Sound Waves of Finite Amplitude, M. J. Lighthill, The University, Manchester. Turbulent Diffusion, G. K. Batchelor and A. A. Townsend, Cavendish Laboratory, University of Cambridge. Atmospheric Turbulence, T. H. Ellison, Clare College, Cambridge. The Mechanics of Sailing Ships and Yachts, K. S. M. Davidson, Experimental Towing Tank, Stevens Institute of Technology, Hoboken, N.J.

Advances in Applied Mechanics, Vol. 4. Edited by H. L. Dryden and Theodore von Kármán. New York, Academic Press, Inc., 1956. 413 pp., illus., diagrs. $10.

Contents: The Turbulent Boundary Layer, Francis H. Clauser. Nonlinear Elasticity, T. C. Doyle and J. L. Ericksen. Physical and Statistical Aspects of Fatigue, A. M. Freudenthal and E. J. Gumbel. Three-Dimensional Boundary Layer Theory, Franklin K. Moore. Dislocation Theory of Plasticity of Metals, G. Schoeck. The Poincaré-Lighthill-Kuo Method, H. S. Tsien. On the Concept of Elastic Stability, Hans Ziegler. Author Index. Subject Index. A bibliography accompanies each paper.

MILITARY AVIATION

Air Power. Asher Lee. New York, Frederick A. Praeger, 1955. 200 pp. $3.75.

Asher Lee worked during World War II on the air intelligence staff of the Royal Air Force. As a specialist on military aviation, he has lectured at staff colleges in several of the NATO countries. Among his previous publications are *The German Air Force* and *The Soviet Air Force*. In this new book he analyzes the whole question of air strategy. Individual chapters deal with a single type of air operation: bombing, fighter defense, transport, antisubmarine, air-borne troops, army cooperation, etc. First are given the lessons which can be learned from the experiences of World War II; then the role each type of operation might play in a future war is assessed. Subsidiary chapters deal with air intelligence and the problems of combining the three services. In the final chapter the author surveys the revolutionary changes in air weapons of the last decade and ventures some prognostications.

POWER PLANTS

High-Speed Combustion Engines; Design, Production, Tests. P. M. Heldt. 16th Ed. Philadelphia, Chilton Company, 1956. 805 pp., illus., diagrs., tables. $12.

The present volume is a complete revision of the 1951 edition. The increase in compression ratios has necessitated a redrawing of some of the standard engine indicator diagrams, torque curves, and bearing-load diagrams. In the chapters dealing with engine components, drawings of actual production parts were usually given, and in many cases these have been replaced or supplemented by drawings of parts of more recent design. To the chapter on "The Working Media," has been added information on the properties of liquified petroleum gases as motor fuels. "Unconventional Engines," the final chapter of the previous edition, has been replaced by a chapter on "Thermodynamics of the Combustion Engine."

STANDARDIZATION

Government-Industry Cooperation in Standardization, Proceedings of the 6th National Conference on Standards, Washington, October, 1955. Sponsored by the American Standards Association and the National Bureau of Standards. New York, American Standards Association, 1955. 97 pp. $3.00.

Thirty addresses are published in this volume, in which major segments of industry, federal and state governments, and the three military services are represented in the standards program presented. The effectiveness of standards in saving money and increasing efficiency are illustrated under the following broad topic discussions: Significant Developments in Standards Activity; Standardization through Government-Industry Cooperation; The Legal Implications of Standardization; Government-Industry Standardization at the Office of Secretary of Defense Level; Government-Industry Standardization at the Army, Navy, and Air Force Level; The Relationship of Industry Standards and Specifications to Those of Government; and Government-Industry Cooperation in International Standardization.

VIBRATION

Measurement of Vibration. Ervin E. Gross, Jr. Cambridge, Mass., General Radio Company, 1955. 60 pp., illus., diagrs., figs.

This booklet covers vibration terms and describes vibration-measuring instruments, procedures, typical examples, and interpretation of results. A short section is devoted to the human response to mechanical vibration.

YEARBOOKS

Aircraft Yearbook, 1955. 37th Ed. Official Publication of the Aircraft Industries Association of America, Inc. Washington, D.C., Lincoln Press, 1956. 479 pp., illus., diagrs. $6.00.

The latest edition of this well-known reference to United States aviation includes descriptions, photographs, and three-view drawings of aircraft in production during 1955; a chronology of aviation events; a directory of information sources in industry and Government; a survey on the latest in air-borne weapons; and current official aviation records.

Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Professors—The Institute of Technology, USAF, has several vacancies for qualified professors or engineers to teach on a graduate and undergraduate level in aeronautical, mechanical, chemical, and production engineering. Employment will be effected in accordance with Civil Service regulations. Grade levels range from GS-9, $5,440 per annum, to GS-13, $8,990 per annum. Applications should be made to the Dean, Resident College, Institute of Technology, USAF, Wright-Patterson AFB, Ohio.

Research Engineers and Physicists—Limited number of key positions available in recently established missile systems research organization. Individuals with interests and capabilities in hypersonic aerodynamics, viscous and heat-transfer problems at high speeds, fundamental processes in nuclear and chemical propulsion schemes, and the behavior and properties of gases at high temperatures are invited to consider association with this new scientific research organization. Address inquiries to: Systems Research Corporation, 13729 Victory Blvd., Van Nuys, Calif.

Structures Engineers—Expansion within the Northrop Structures Department has created several positions for qualified engineers in thermo-structural analysis, high-speed computing technique development, and structural materials research. There are also challenging opportunities for flutter engineers, loads engineers, and weight engineers. Diversified assignments cover all phases of missile and long-range interceptor projects. For immediate consideration, write: Engineering Personnel Manager, Northrop Aircraft, Inc., 1001 East Broadway, Hawthorne, Calif., or call ORegon 8-9111, Ext. 1893 (Hawthorne).

The number preceding the notice represents the Box Number of the Institute of the Aeronautical Sciences to which inquiries should be addressed.

Propulsion Engineers—The Theoretical Propulsion Group is now being organized at Chance Vought Aircraft, Inc., and numerous new openings are available at many levels for qualified propulsion engineers with a B.S. degree and 2 or more years' experience or with an advanced degree and no experience. The work in this group is devoted to overall aircraft propulsion systems and system components—including all phases of prop, jet, and nuclear propulsion—and, in general, is dedicated toward obtaining an optimum marriage between a propulsion system and an air frame. More specifically, the work deals with such topics as engine inlets and outlets, internal cycle analysis, overall propulsion system analysis and relative merits, heat transfer, environmental gas conditioning, and high-energy fuels. Timewise, the work deals with aircraft propulsion system from today to 10 years in the future. These openings offer unique opportunities to analytical, design, and development propulsion engineers to broaden themselves by working with overall propulsion systems as applied to flight vehicles and later to rotate on an optional basis into groups doing propulsion project work or preliminary aircraft design work. Salaries are commensurate with qualifications and are at the premium level. Address résumé or further inquiry to: Dr. W. J. Hesse, Supervisor, Theoretical Propulsion Group, Chance Vought Aircraft, Inc., P.O. Box 5907, Dallas, Tex.

Engineers—American Airlines Engineering Division located at Tulsa, Okla., has openings for qualified engineers in the field of air-line operations, maintenance, and equipment development, including power plants (turbine, turboprop, and reciprocating engines), structures, electronics, air conditioning, accommodations, and associated ground and test equipment. Openings are the result of continued normal growth of current operating fleet and introduction of turboprop and jet aircraft and power plants. Please send résumé to: W. C. Lawrence, Assistant Vice-President—Engineering, American Airlines, Overhaul & Supply Depot, Tulsa, Okla.

Aeronautical Engineer—To teach courses in aeronautical engineering fundamentals. California State Polytechnic College, with an engineering enrollment of approximately 1,800 students and 70 staff members, offers an engineer the opportunity to work with students in a unique instructional program leading to a B.S. in Aeronautical Engineering. Practical experience in industry is of prime importance because instruction is based on a balanced combination of theory and practice. Teaching experience is desirable but not essential. If you have a Bachelor's degree or equivalent and up-to-date industrial experience, you can qualify for a starting salary of $5,000 to $5,500 for the academic year of approximately 9 months. Please send résumé of your education and experience and names of four references to: Dean of Engineering, California State Polytechnic College, San Luis Obispo, Calif.

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Engineers—Doak Aircraft Co., Inc., Torrance, Calif. (Los Angeles County), has a number of unusually interesting openings for aeronautical engineers in the design and development of a new vertical take-off aircraft. Challenging opportunities for men with experience and training in the fields of aerodynamics, structural design, stress analysis, mechanical design, and engineering drafting. The development of this VTOL aircraft is being conducted under a prime government contract. Please send résumé including salary requirements to: N. E. Nelson, Chief Engineer, Doak Aircraft Co., Inc., 22309 South Western Avenue, Torrance, Calif.

Aeronautical Engineers—The Navy Department, Bureau of Aeronautics, has a number of positions available in the following fields of aeronautical engineering including research and development on aircraft and guided missiles, structural loads, vibration and flutter, aerodynamic heating, power plants, cruise control, performance, ships installation of aircraft and missiles, and related mechanical, electrical, and electronic components. Salaries for most positions are at the GS-11, $6,390 per annum, and GS-12, $7,570 per annum, levels, although some positions may be available at the GS-13, $8,990 per annum, level. Positions require 2½ to 5 years' experience. Standard Form 57, Application for Federal Employment, should be sent to the Bureau of Aeronautics, Personnel Division (PE-202), Main Navy Building, Washington 25, D.C.

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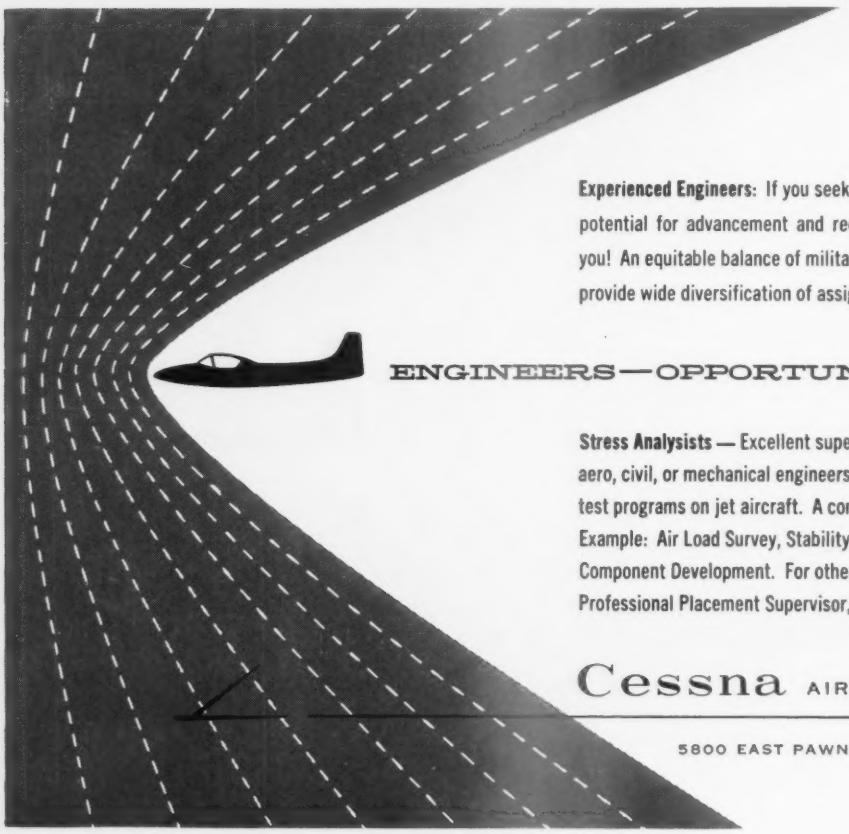

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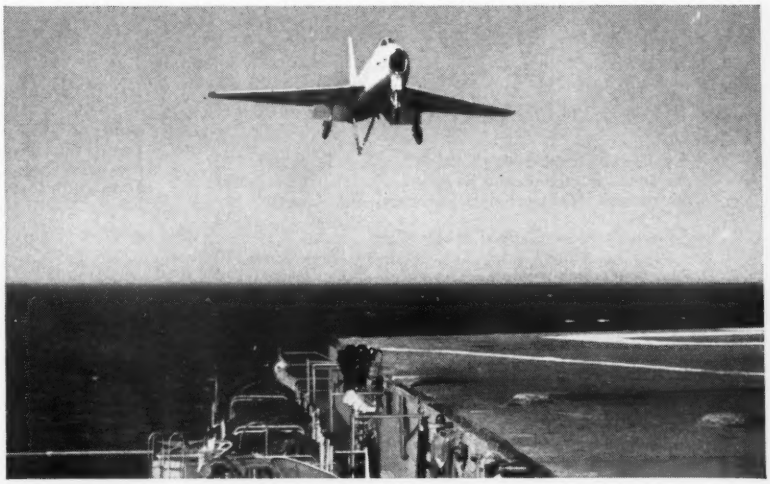

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